Essays on Institutions, Firm Funding and Sovereign Debt

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Abstract

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This thesis explores the effects of institutions on macroeconomic performance. It does so in two main chapters, a summary of each of which is given below. In the first main chapter of the thesis, the interactions between government spending, government borrowing, political corruption and political turnover were examined. Incorporating these factors in a sovereign default model, we show how sovereign default decisions and business cycle fluctuations are affected by the level of corruption. In particular, we show that when there is turnover, corruption can generate higher risks of default and higher credit spreads when there is enough stability. Intuitively, we establish that a change in power from a less corrupt to a more corrupt government is more likely to cause default than the reverse. The results also shows that households suffer welfare losses as a result of corruption. As regards business cycles, the general effect of corruption is to alter business cycle statistics. Further, we estimate an empirical model using data on sovereign default, corruption, political stability and other macroeconomic variables for a sample of emerging economies. The results of this provide strong evidence of a positive relationship between both corruption and political stability and sovereign default.

The second main chapter of the thesis looks at the effects of limited financial contract enforcement in a dynamic stochastic general equilibrium framework where firms have access to both internal and external means of finance. The results shows how limited enforceability affects fluctuations in key macroeconomic variables (e.g., output, employment and price) through its impact on key financial variables (e.g., interest rates, risk premium, default risk and leverage). In particular, we find that weaker enforcement tends to amplify the effects of shocks, creating greater volatility, as well as lowering small firm funding. We provide some empirical evidence to support our results. Using cross-country data on measures of financial market imperfections, we find that limited enforcement has a negative effect on output and that this effect is exacerbated by poor credit information. We also find that weaker contract enforcement is associated with higher output volatility.
Declaration

I, Adams Sorekuong Yakubu Adama, hereby declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.
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Dedication

To the loving memory of my late God-father, Alhaji Abdul-Rahman Musah

a.k.a Mba Musah (Wilhem)

&

To the loving memory of my late father, Naa Adama Saaka.
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Pursuing a doctoral degree in economics is a long and sometimes a tough journey. I would first and foremost thank the Almighty God for His guidance throughout this Ph.D journey. I would also like to thank all those who made this journey a joyful one. In particular, I am greatly indebted to my supervisors, Professor Keith Blackburn, Dr. Macnamara and Dr. Michele Berardi, for their constructive comments, suggestions, support and guidance throughout my research. I would also like to thank them for their time and energy spent reading through the draft copies of this thesis. I wish also to thank the School of Social Sciences and the Economics Department for funding my Ph.D programme.

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During my Ph.D programme, I had the opportunity to present my research (including two of the chapters in this thesis) at international conferences including the International the CSAE 26th Conference on Economic Development in Africa (Univer-
sity of Oxford), 2nd Annual International Interdisciplinary Conference on Challenges to Development in Africa (Catholic University, Nairobi, Kenya), the Royal Economic Society (RES) 2015 conference. I also presented my work in a number of seminars at the University of Manchester, especially the Center for Growth and Business Cycle Research (CGBCR) and Macroeconomics RAG seminar series. I wish to acknowledge the suggestions, critics and comments I received from the participants.

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And to everyone who has supported me either directly or indirectly, have my heartfelt gratitude.
Chapter 1

Thesis Introduction

North (1989) defines institutions as “rules, enforcement characteristics of rules, and norms of behaviour that structure repeated human interaction” (p.1321). In other context, institutions are defined as humanly devised constraints that shape interaction between people (see North (1990)). Fundamentally, in North’s view, the quality of these institutions improves with limitations imposed on executive power. Generally, institutional quality consists of certain key scopes such as voice and accountability, political stability, rule of law, control of corruption, ease of doing business, regulatory quality amongst others.

The importance of institutions in determining economic performance cannot be underrated. By establishing clear and enforceable property rights, that minimise transaction costs and reduce the threat of coercion, good quality institutions can be decisive in an economy’s prospects for growth and development. The importance of institutions is well documented as is the diversity in institutional quality across different states (see Knack and Keefer (1995); Rodrik et al. (2004); Hall and Jones (1999a)). Rodrik et al. (2004) claim that good institutions is one of the most important factors to economic development whilst Hall and Jones (1999a) find that cross-country differences in institutional quality are a major source of cross-country differences in capital accumulation, productivity and per capita output.

The state is expected to provide the legal framework, infrastructure and stability that is necessary for the creation of a favourable institutional environment. In many
instances, however, the state often fails in this role, leaving room for rent-seeking activities (see Elliott (1997); Infante and Smirnova (2009); Treisman (2003); Ofer (2003)). There is empirical evidence that rent-seeking is related (positively) to institutional weakness (see Mauro (1995); Acemoglu and Johnson (2004)). Interestingly, rent-seeking could represent a mechanism that might improve economic performance in the presence of weak institutions. This is the so-called “speed money” hypothesis, according to which bribes paid to public officials may be a means of circumventing cumbersome rules and regulations (red tape) that impede business efficiency. From a different perspective, it has been argued that rent-seeking may be the necessary price to pay for correcting institutional weaknesses. In other words, society may face a trade-off between government failure and market failure (see Acemoglu and Verdier (1998, 2000); Djankov et al. (2003); Acemoglu and Johnson (2004); Infante and Smirnova (2009)). Acemoglu et al. (2003) in their study of the effect of institutions on macroeconomic policies observed that there are deeper institutional causes of economic instability and poor macroeconomic performance, such as law and order.

One manifestation of weak institutions is corruption. Though there is no one acceptable definition of corruption, Transparency International, generally, defines corruption as the abuse of entrusted power for private gain, by especially public sector officials. Public sector corruption is defined by Blackburn et al. (2006) as “the abuse of authority by bureaucratic officials who exploit their powers of discretion, delegated to them by the government, to further their own interests by engaging in illegal, or unauthorised, rent-seeking activities” (p.2448). It is in this light that the World Bank\(^1\) argues that corruption is “the single greatest obstacle to economic and social development. It undermines development by distorting the rule of law and weakening the institutional foundation on which economic growth depends”. The relationship between corruption and other macroeconomic variables has been studied extensively in the literature (see Mauro (1995); Knack and Keefer (1995); Li et al. (2000); Dreher and Herzfeld (2005)). Mauro (1995) conducts an empirical investigation into the relationship between corrup-

\(^1\)http://www.worldbank.org/
tion and economic growth, concluding that corruption has a significant negative impact on investment. Knack and Keefer (1995) and Li et al. (2000) find similar results, as do Dreher and Herzelfeld (2005) who calculated that an increase in International Country Risk Guide (ICRG) index of corruption by one point reduces growth by 0.13% points and GDP per capita by US$ 425. Corruption can also have distributional effects, with several studies identifying a positive correlation between the level of corruption and the degree of income inequality (see Li et al. (2000)).

One of the major channels through which corruption can affect growth is its impact on public policy. There are many ways in which this might occur, some more direct than others. On one side of the government’s balance sheet, corruption can cause a misallocation of public expenditures away from growth-promoting areas (such as education and health) towards bribe-generating areas (such as military and defence) (see Gupta et al. (2001); Mauro (1998); Tanzi and Davoodi (1997)). For the same reason, expenditures may be misallocated away from the most to the least cost-effective means of public procurement, producing inefficient and inflated levels of spending (see Blackburn et al. (2011)). On the other side of the balance sheet, corruption can lead to a loss of tax revenues and other public funds, as evidenced in a number of studies (see Tanzi and Davoodi (2000, 1997); Ghura (1998); Imam and Jacobs (2014)). This may compromise the delivery of pro-growth social programmes and, in doing so, weaken individuals’ incentives to save and invest (see Blackburn and Sarmah (2008)). It may also force the government to raise taxes or to seek additional means of distortionary finance, including inflationary finance (see Al-Marhubi (2000); Blackburn and Powell (2011b)).

In a different vein, corruption in regulation can cause a dilution of property rights and an escalation of the costs of doing business, each of which may impede innovation and entrepreneurship (see Hall and Jones (1999b); North (1990); Sarte (2000)).

Beyond public policy, there are other ways in which corruption can affect economic performance. One of these is by inducing a misallocation of talent away from productive (entrepreneurial) activities towards non-productive (rent-seeking) activities (see Ehrlich and Lui (1999); Murphy et al. (1991)). Another is by imposing deadweight
losses on society through the costs of trying to conceal and expose corrupt behaviour (see Blackburn et al. (2006); Blackburn and Forgues-Puccio (2007)).

Corruption can affect other macroeconomic variables and other aspects of macroeconomic policy. Of particular interest to this thesis is the effect of corruption on government finance especially when the government relies heavily on borrowing. Corrupt public officials may confiscate loaned funds or block other sources of government income, thereby limiting the government’s ability to meet its debt obligation. For instance in Russia more than US$4 billion in IMF loans was believed to have disappeared shortly before Russia’s default in 1998 (see Ciocchini et al. (2003)). Work by Haque and Sahay (1996), Tanzi and Davoodi (1997), and Johnson et al. (1999) shows that higher levels of corruption are associated with lower tax revenue, which could otherwise be used by the government to repay its debt. Ciocchini et al. (2003) investigate the effect of corruption on sovereign bond spreads, observing that higher levels of corruption are associated with higher spreads. The same authors observe that corrupt governments require high liquidity which induces them to borrow even under very high spreads. Transparency International reported that corruption was one of the triggers of the Greek debt crisis (see Corruption triggered Greek Debt Crisis-Transparency International).

Another issue that is particularly relevant to this thesis is the effect of institutional weaknesses on the functioning of financial markets. Good legal institutions (rule of law in the form of quality of property rights, contract enforcement, the police, and the courts etc.) are generally argued to be essential for fostering financial development. Such institutions play a vital role in protecting investors through the enforcement of property rights and contractual arrangements. This creates room for risk sharing and a willingness of investors to supply funds to firms (see La Porta et al. (1997); López de Silanes et al. (1998); La Porta et al. (2000)). Albuquerque and Hopenhayn (2000) argue that better enforcement of contracts has serious implication for the funding of small firms and growth. Yet, the inability of these legal institutions to enforce financial

\footnote{http://www.spiegel.de/international/europe/european-debt-crisis-greek-corruption-booming-says-transparency-international-a-681184.html}
contracts is what we refer to as weak (limited or imperfect) contract enforcement. That is to say, limited contract enforcement is the difficulty with which lenders can recover defaulted loans. Others, including the World Bank, have likened (limited) contract enforcement to the time and cost for resolving commercial dispute through courts—cost of contract enforcement.

In light of the foregoing discussion, this thesis is broadly concerned with the relationship between institutional quality, government debt and firm funding together with the implications of this for macroeconomic outcomes. The thesis seeks to contribute to the (theoretical) literature on sovereign default by studying specifically the influence of corruption and political turnover on sovereign default decisions. It does so within the context of a Dynamic Stochastic General Equilibrium (DSGE) model which allows for the random political turnover of alternative types of government that have different propensities to be corrupt. We contribute to the empirical literature of sovereign default by analysing the influence that corruption and political factors could exert on sovereign default risk. We distinguish between corruption and political stability (which is not done in the literature (see Chapter (2) for details) in order to investigate the influence that each independently exerts on sovereign default. We contribute to literature on financial development by studying the upshot of limited financial contract enforcement (institutions) on financial markets and macroeconomic outcomes. Specifically, our first line of contribution is to the literature on agency costs, asymmetric information and financial development where we study the role of limited contract enforcement in a Dynamic Stochastic General Equilibrium (DSGE) framework. We do so by allowing for the possibility of the firm being able to default on bank loans when it is still solvent, though a defaulting firm faces the prospect of being punished if it is caught. Empirically, we contribute to the literature on macroeconomic performance and financial development by using data that has current trends covers a wide range of countries. The thesis consists of two main essays; a summary of which is given below.

In the first essay we study sovereign borrowing and sovereign default risk in a dynamic general equilibrium model of corruption and political turnover. Many govern-
ments across the world borrow to finance their budget deficits. An obvious question is why do some governments borrow more than others and why do some governments default more than others? Evidence suggests that weak institutions in the form of corruption may be the answer. We provide an explanation for this by demonstrating how corruption (modelled as the embezzlement of public funds) may influence sovereign borrowing and default decisions on the part of alternating incumbent governments with different propensities to be corrupt. We show that when there is turnover between governments with different governments, corruption can generate high default risk and high credit spreads, but only when there is enough stability. We establish that a change in power from a less corrupt to a more corrupt government is more likely to increase this default risk than the reverse. We also find that welfare loss to households is increasing with the level of corruption. As motivation and support for our analysis, we present some empirical evidence to show that corruption is, indeed, associated with higher risks of default. The empirical evidence also shows a strong positive relationship between political stability and risks of default.

In the second essay we study financial intermediation and firm financing in a dynamic general equilibrium model of capital market imperfections resulting from institutional weaknesses. The legal enforcement of contracts plays an important role when contractual issues cannot be solved amicably between lenders and borrowers especially in emerging economies. Yet the legal institutions required for this are often very weak or non-existent implying that contract enforcement is limited. We explore the implications of this by considering the effect of poor quality institutions (imperfect contract enforcement) on firms’ financial arrangements with lenders, firms’ decisions to default and firms’ access to working capital.

We establish a pro-cyclical risk premium following a positive aggregate productivity shock. However, we find that a shock to net worth in the form of one-time wealth transfer from entrepreneurs to households results in a counter-cyclical risk premium. This transfer reduces entrepreneurial net worth and causes a fall in the supply of capital which then pushes up the price of capital. The fall in net worth also results in
increasing demand for external finance which in turn causes a rise in the probability of default and the lending rate. The risk premium depends on the probability of default, the price of capital, the lending rate and the strength of contract enforcement. Overall, the lending rate, the risk premium and the default probability are increasing in the degree of limited contract enforcement. This risk premium provides the key mechanism through which the effects of shocks are amplified by limited contract enforcement; the latter which also results in greater output volatility. Consequently, high degree of limited contract enforcement imposes a negative effect (in the form of high lending rate) on small firms (which are forced to rely more on external finance) seeking to borrow in order to finance investment. This is particularly onerous for smaller firms, the growth of which is therefore impeded. As motivation and support for our analysis, we present some empirical evidence which shows that a weaker enforcement (or higher cost of enforcement) of financial contracts is associated with a lower level, lower growth rate and higher volatility of output.

The rest of the thesis is organised as follows. In Chapter (2), we investigate the influence that corruption and political turnover (risk) have on sovereign default decisions. We study the effect of limited financial contract enforcement on macroeconomic outcomes in Chapter (3). In Chapter (4), we present the conclusion of the thesis, also highlighting its limitations and directions for further research.
Chapter 2

Corruption and Political Turnover
in a Sovereign Default Model

2.1 Introduction

Business cycles in emerging economies vary from their developed counterparts. Such economies are typically characterised by relatively high interest rates and interest rate spreads, high output volatility, low output per capita, weak institutions, high levels of corruption, high political instability and high frequencies of sovereign default. The last of these phenomena (like most of the others) has attracted the attention of academics and policymakers for a long time, and a renewed interest has been ignited by recent events in the world. This chapter of the thesis seeks to contribute to the literature on sovereign default by studying specifically the role of corruption in influencing default decisions. It does so within the context of a Dynamic Stochastic General Equilibrium (DSGE) model which allows for the random political turnover of alternative types of government that have different propensities to be corrupt. Corruption manifests itself as the embezzlement of public funds. Specifically, public sector corruption is defined as “the abuse of authority by bureaucratic officials who exploit their powers of discretion, delegated to them by the government, to further their own interests by engaging in illegal, or unauthorised, rent-seeking activities” (Blackburn et al. 2006, p.2448). The results of the analysis highlight the important role that corruption can
play in determining the risk of default, a role that is evidenced by the data.

Sovereign default has been attributed to various causes, both economic and political. In their seminal work, Hatchondo et al. (2009) introduce political factors into the modelling of sovereign default which they claim to have accounted for defaults in Brazil during 2002 and Argentina during 2001. The authors present a model with political turnover, where different government types are distinguished in terms of their degree of impatience which influences their willingness to pay off debt. In turn, this affects the equilibrium bond spread through a direct impact on each type's borrowing opportunities. It is shown that sovereign default may be triggered when the government changes from a more patient to a less patient type, provided that there is enough political stability. This suggests that political turnover may have significant implications for sovereign default decisions. The model also illustrates a non-monotonic relationship between political stability and default probability which is in line with the political turnover models of Amador (2003) and Cuadra and Sapriza (2008), where political stability affects sovereign bond spreads through future utility flows. Though default episodes have mostly occurred in periods of downturns, there is, nevertheless, evidence that a considerable number of default episodes occur when output is above its long-run trend (see Tomz and Wright (2007); Hatchondo et al. (2009)).

The foregoing analyses yield important insights, though one issue that is not addressed, but which merits attention, is the role of corruption in influencing the risk of sovereign default. This is particularly pertinent for emerging economies, and there are good reasons for thinking why corruption may be important for default decisions. For instance, a corrupt policymaker may be willing to borrow substantial funds even with high interest rate spreads in order to create opportunities for appropriating resources. As a result, corruption may lead to a higher incidence of default if loan repayments become excessive. Ciocchini et al. (2003) studied the effect of corruption on sovereign bond spreads in emerging economies and observed that high levels of corruption are associated with high spreads. Importantly, the authors argue that corrupt governments need liquidity which results in high borrowing even with very high spreads. Further-
more, if corruption leads to a drain on loaned funds and other sources of government income, then it may limit the government’s ability to meet its debt obligations. For instance, in Russia more than $4 billion in IMF loans apparently disappeared shortly before Russia’s default in 1998 (see Ciocchini et al. (2003)). Similarly, Haque and Sahay (1996), Tanzi and Davoodi (1997), and Johnson et al. (1998) observe that higher levels of corruption are associated with lower tax revenues, which would in turn lower the government’s ability to repay its debt. One observation is that most of the countries that default seem to be the most corrupt. In addition, the data suggests that there is a strong correlation between sovereign default, corruption and political turnover.

In spite of the above, little or no attempt has been made to explore the inter-linkages between corruption and the risk of default. This paper seeks to do so. The analysis is based on a DSGE model in which different government types alternate in power. Corruption takes the form of a government’s illegal consumption of public funds, which impacts on the decision to default. The government borrows in order to smooth household consumption, although it is only partially benevolent in this respect due to its proclivity towards corruption. A government may be either of two types—a more corrupt or a less corrupt type—which alternate in power with a certain probability. The government in office makes a decision about whether or not to default by trading off the benefits and costs associated with this. The benefits of defaulting are the avoidance of debt repayments, whilst costs are a loss of output in the following period. We show how default decisions, together with business cycle fluctuations, are affected by the level of corruption. We find that more corrupt governments are more likely to default, conditional on the same endowment and initial debt. Moreover, the presence of political turnover makes it possible for corruption to generate high default risk and high credit spreads, but only when there is enough political stability. With turnover, the less corrupt government pays a premium to lenders to compensate them for the possibility that the more corrupt government will come into power next period and default. When there is a lot of instability, the less corrupt government avoids increasing debt levels to the point where the corrupt government would default, result-
ing in lower credit spreads. However, when there is enough stability, the less corrupt government is willing to borrow at levels which the more corrupt government would default. While the probability that the high type comes into power is low, this still results in higher default risk and higher credit spreads. We also compute the welfare loss to households as a result of corruption and show that this loss is increasing with the level of corruption.

To set the scene for our theoretical analysis, we first conduct an empirical investigation into the determinants of sovereign default. Using data on a broad sample of emerging economies, we find that, amongst other factors, both corruption and political stability have a significant positive influence on sovereign default.

2.1.1 Related Literature

2.1.1.1 Theoretical literature

This paper is closely related to the models of Cole et al. (1995), Alfaro and Kanczuk (2005), and Hatchondo et al. (2009). These models study sovereign default with heterogeneous borrowers where a patient policymaker is replaced by an impatient policymaker. Cole et al. (1995) and Alfaro and Kanczuk (2005) focus on equilibria in which patient policymakers never default and impatient policymakers always default. Hatchondo et al. (2009) consider a political process similar to the one used by Cole et al. (1995), and Alfaro and Kanczuk (2005), but differ in the government’s choice of optimal borrowing level and in both policymakers being able to default. They show that if there is enough political stability and a patient government also encounters poor economic condition, a default is likely to be triggered by political turnover. In addition, they find that the presence of political turnover can result in an increase in the volatility of the spread paid by patient governments in politically stable economies. We study sovereign default in an environment similar to that of Hatchondo et al. (2009) and find that the presence of political turnover results in an increase in the volatility of spread paid by both types of governments and this increase is greater with the more corrupt type.
Information on borrower types to lenders in the literature is mixed. Many recent models of sovereign default with heterogeneous borrowers assume that lenders cannot directly observe a borrower’s type (see Chatterjee et al. (2007)). Hatchondo et al. (2009), on the contrary, assume that the type of policymaker in power is public information to lenders. Hatchondo et al. (2009) also allow policymakers to choose debt levels from a continuum. We make similar assumptions as Hatchondo et al. (2009).

A number of models (see Cole et al. (1995); Alfaro and Kanczuk (2005)) assume representation of borrowers with stochastic preferences where borrower types change over time. Hatchondo et al. (2009), on the other hand, assume a representation of political processes, similar to Amador (2003), and Cuadra and Sapriza (2008) but where borrowers of different types alternate in power. Amador (2003), and Cuadra and Sapriza (2008) in their setup assume that types only differ on the optimal allocation of resources within each period and receive the same treatment from lenders. They also assume that political stability affects the equilibrium spread mainly through its impact on the weight of future utility flows. On the contrary, Hatchondo et al. (2009) in their setup assume that the two types differ in their willingness to pay. They equally argue that political stability affects equilibrium spreads mainly through the direct effect it puts on the borrowing opportunities of a government. In our setup, the two types differ in their willingness to pay and the risk of being replaced, the latter effect exacerbated by the propensity of a type to be corrupt. We focus on a single discount factor case, whilst the other models (see Amador (2003); Cuadra and Sapriza (2008); Hatchondo et al. (2009)) consider different discount factors as a representation of types. In our setup, types are represented by their propensity to be corrupt. We argue that political stability, which is aggravated by how corrupt a type is, affects equilibrium spreads through its impact on the policymaker’s borrowing opportunities and how lenders perceive types.

Earlier studies (see Aguiar and Gopinath (2006); Chatterjee et al. (2007)) have used shocks to endowment growth rate and shocks to borrower’s discount factor as tools to smooth out the equilibrium bond price function faced by the borrower and as a
mechanism in generating a higher spread and higher spread volatility. The introduction of political turnover in the Hatchondo et al. (2009) model serves as the mechanism through which smoother bond price functions are delivered. In our setup, building on Hatchondo et al. (2009), political turnover impacts on the bond price function and also amplifies the effect of corruption in the model.

2.1.1.2 Empirical literature

The empirical literature on the determinants of debt crisis is broad (see Schimmelpfennig et al. (2003); Laušev et al. (2011)). Earlier studies (see Frank and Cline (1971)) have made findings on the possibility of predicting debt crisis. On the contrary, other studies (see McFadden et al. (1985)) have found that predicting debt crises might be difficult. McFadden et al. (1985) in their study on finding probabilities of debt crisis using data for 93 countries over the period 1970-1982, conclude that predicting debt crises in advance might be difficult even though an econometric model can help to explain sovereign debt problems. To this effect, they find debt burden, the level of per capita income and real GDP growth, to mention few, as significant predictors of debt crisis.

Commonly included in the econometric models are short-term financial variables like debt-GDP ratio and long term variables like GDP growth. Specifically, Schimmelpfennig et al. (2003) as cited in Laušev et al. (2011) find high external debt to GDP ratio and short term debt to be highly associated with debt rescheduling. Detragiache and Spilimbergo (2001a) find the importance of liquidity factors such as short-term debt, debt service, and the level of international reserves as determinants of debt crises. They do not only identify countries that are more open as in a better position to service their debt, but find inverse relationship between liquidity of a country and the probability of default. Edwards (1984), Min (1998), and Rowland and Torres (2004) recognise the importance of various macroeconomic variables in determining credit spreads.

Besides economic variables, political risk and institutional variables have often
been considered to play an important role in predicting sovereign debt crises among emerging market countries. Balkan (1992), one of the earliest attempted studies on this issue, finds an inverse relationship between probability of rescheduling and the level of democracy for a country, on the one hand, and a direct relationship between probability of rescheduling and political instability, on the other hand. Furthermore, Verma (2002) finds that more democratic countries tend to default more, whilst Bordo and Oosterlinck (2005) observe that half of the default incidents during 1880-1913 occurred around periods of political turnovers. Citron and Nickelsburg (1987) and more recently Georgievska et al. (2008) uphold the importance of political factors in determining debt rescheduling probabilities. According to Baldacci et al. (2011), higher political risk is also associated with higher spreads. A number of recent studies have also stressed the significance of such political variables in determining sovereign default and debt rescheduling (see Ul Haque et al. (1998); Reinhart et al. (2003); Santiso (2003); Van Rijckeghem and Weder (2004); Sturzenegger and Zettelmeyer (2006); Moser (2007); and Laušev et al. (2011)).

Kraay and Nehru (2006), one of the earliest attempted studies on debt crisis and institutions, find the quality of institutions and policies to have major effect on debt rescheduling. Similarly, Butler and Fauver (2006) identify the quality of a country’s legal and political institutions as having a major role play in determining sovereign credit ratings. In addition, Ciocchini et al. (2003) study the effect of corruption on sovereign bond spreads in emerging economies and observe that high levels of corruption are associated with high spreads.

The impact of past debt repayment records on current and future rescheduling have been investigated in a number of studies. Specifically, McFadden et al. (1985), Li (1992), Aylward and Thorne (1998), and most recently Laušev et al. (2011) have found debt repayment history as a strong determinant of future debt crisis.

We contribute to the empirical literature by analysing the influence that corruption and political factors could exert on sovereign default risk. We distinguish between corruption and political stability (which is not done in the literature (see Balkan (1992);
Li (1992); Verma (2002); Bordo and Oosterlinck (2005) and Laušev et al. (2011) in order to investigate the influence that each independently exerts on sovereign default. We find a result that is puzzling. Using data on a broad sample of emerging economies over the period 1984-2008, we find that, amongst other factors, both corruption and political stability have a significant positive effect on sovereign default. We contribute to the theoretical literature by studying how corruption together with political turnover can affect sovereign default decision in a dynamic general equilibrium setting. The rest of the paper is organised as follows. In Section (2.2), we present the empirical analysis of the determinants of sovereign default. In Section (2.3), we set out the theoretical model that we use to study the relationship between sovereign default and corruption. The theoretical model is intended to find solution to the problems, such as endogeneity, that our empirical model might run into. In Section (2.3.2), we solve the model. In Section (2.4), we calibrate the model and present our main results. In Section (2.5), we make some concluding remarks.

2.2 Empirical Observations

This section looks empirically at the influence that corruption and political factors have on sovereign default. Our main objective is to evaluate the extent to which corruption and political factors have direct or indirect effects on the risk of default. Taken together, our results suggest that there is a significant positive association between sovereign default and both corruption and political stability, controlling for other important determinants of default. This central finding remain fairly robust to a battery of sensitivity analyses, including alternative specifications.

2.2.1 Data Sample

and the International Country Risk Guide by the Political Risk Services (PRS). We consider the following variables as potential predictors of sovereign default: corruption, political stability and various controls such as external debt, annual GDP growth and logarithm of GDP Per Capita. We focus on emerging economies, where the selection of countries is based on the availability of data and also controlling for outliers. Variables used in the estimation and the summary statistics are detailed in Table (2.7.1.2) and Table (2.7.1.3), respectively. Among these variables, GDP per Capita is the most volatile followed by political stability and then corruption. That is volatility of 2.411, 1.891 and 1.039, respectively.

2.2.1.1 Dependent Variable

Existing studies on sovereign debt crisis show that there is no laid down definition of a sovereign debt crisis, a sovereign default episode, or a sovereign debt rescheduling event (see for example Kraay and Nehru (2006); Schimmelpfennig et al. (2003); Laušev et al. (2011) and Ciarlone and Trebeschi (2005)). Generally, sovereign default or sovereign debt rescheduling is any failure by a nation to meet its debt obligations. This may involve either missing a scheduled payment of principal or interest. Specifically, the IMF and the World Bank have considered rescheduling agreements on external debt as sovereign defaults. In our context the dependent variable is sovereign default. We consider a country as having defaulted if there was an outright default of debt or if there was reported reschedule of the principal or interest, as is reported in Standard and Poors, Moodys, World Bank Development Indicators, the IMF and World Bank–Global Development Finance (1991, 2006, 2012). Using this data, we establish the following criterion for determining the dependent variable (default): A default is registered if a country defaults or reschedules its debt or the interest on its debt in a given year. As argued in the literature rescheduling could be inability on the part of the borrower to settle the terms of the contract and can be treated as a proxy for default. We look at sovereign default episodes for emerging economies over the period 1984-2008. We use
25 countries after controlling for outliers as displayed in Table (2.7.1.1).

2.2.1.2 Independent Variables

We undertake our analysis using macroeconomic variables, otherwise known as solvency variables, as controls and institutional variables that normally explain a country’s sovereign debt rescheduling or default risk. These variables can be put into the following categories: (a) institutional variables, (b) macroeconomic/solvency variables, (c) past variables (past default record, past of institutional variables and past macroeconomic variables).

(a) Institutional Variables

(i) Corruption

Corruption has been identified as a major political risk factor (see Political Risk Services (PRS\(^1\))). This risk in corruption results from the fact that at some point in time some major scandal could be revealed, which has the propensity to provoke tension and cause a fall or overthrow of the government. This could further bring about a readjustment in the country’s political institutions, a breakdown in law and order, making the country unstable and ungovernable (see PRS). In an assessment of corruption, PRS (2008) has identified “financial corruption in the form of demands for special payments and bribes connected with import and export licenses, exchange controls, tax assessments, police protection, or loans” (p.31) as the most common form of corruption encountered by business. We use the International Country Risk Guide Index (ICRG) measure of corruption by PRS which uses a scale of 0-6 (6 is the highest rank of transparency) that we convert to 0-6 (to capture the level of corruption than transparency), where 6 is the highest rank of corruption.

\(^1\)http://www.prsgroup.com/
The (Un)reliability of Measures of Corruption

Corruption data has been used widely in empirical studies. Nevertheless, the reliability of it measurement still remains an issue in empirical studies. A reliable measure of corruption should be one that objectively quantifies the frequency and the magnitude of corruption over time and across countries, which is often impossible (see Swaleheen (2011)). However, as a result of the lack of objective measure of corruption, current empirical studies on corruption mostly use subjective measures by Transparency International (TI), the World Bank (WB) and Political Risk Services (PRS). Whilst the TI and WB measures of corruption are composite indices based on individual surveys of corruption, the PRS measure is an expert rankings by a specialised institution. It measures corruption that exists within the political system which has the ability to affect foreign investment through distortion in the economic, financial and business environment. Among the subjective measures available, the ICRG measure of corruption by PRS is widely accepted as being reflective of the frequency and magnitude of corruption. Data for this measure is available from 1984. Also due to its broad coverage of countries, it has had wide usage (see Knack and Keefer (1995); Braun and Di Tella (2004); Dreher and Siemens (2003); Dal Bó and Rossi (2007); Swaleheen (2011) and Laušev et al. (2011)).

(ii) Political Stability

In our attempt to examine the effect of political turnover on sovereign default risk, we use the Political Rights Index (PR) from Freedom House as a measure of political stability. This measure has been used by Verma (2002) as a proxy for democracy which the author argues is sometimes equated with political stability. The PR is measured on a scale of 1-7 which we convert to 0-10, where 10 represents the best rating of political rights. Freedom House (https://freedomhouse.org) recognises that “Free elections provide long-term political stability and allow citizens to peacefully replace ineffective or corrupt leaders. And independent media provide a check on government,
verifying official claims of success and exposing abusive practices”. It is in the light of this that we use the Political Rights Index as a proxy for political stability in our work.

It must be pointed out that the measures of corruption and political stability, especially the ICRG measures, do not include sovereign default risk (the dependent variable) in country ratings. By this, we avoid a possible double counting problem that would result from having the dependent variable regressed on a variable that include itself.

(b) Macroeconomic/Solvency Variables

Several macroeconomic variables which may predict sovereign default are used as controls in our estimation. Included amongst these are external debt-GDP ratio, logarithm of GDP per Capita and the annual growth rate of GDP. Data on all of these are taken from the World Development Indicators (WDI).

GDP growth rate which captures the current economic performance of a country has been argued to have a negative impact on the probability of default (see Laušev et al. (2011)). Similarly, GDP per Capita which captures the level of development of a country has been argued in the literature to have a negative relationship with the sovereign default probability (see Feder and Just (1977) as cited in Laušev et al. (2011)). In related studies (see Williams (2014)), GDP per Capita and growth of GDP per Capital have both been used to control for differences in financial system development and economic cycle effects. It is also argued that a country that increases its external debt in relation to its GDP is likely to have unsustainable debt which could in turn increase the probability of default. Accordingly, a positive relationship between external debt-GDP ratio and the probability of default is expected.
(c) Past Default/Rescheduling Records and Past of Current Explanatory Variables

Previous studies on sovereign debt have found evidence of past debt repayment records having positive effect on future default (see McFadden et al. (1985); Aylward and Thorne (1998); Li (1992) and Laušev et al. (2011) etc.). Following these findings, we include past default record as an explanatory variable. Similarly, the inclusion of the past of explanatory variables is to capture the impact of the previous state of the economy on the current one (see McFadden et al. (1985); Balkan (1992) and Pestova (2015)). McFadden et al. (1985) argue that the reason for the inclusion of the lagged explanatory variables is to reduce the problem of simultaneity.

2.2.2 Model Specification

A probit model is used to test the correlations of the macroeconomic and political predictor variables with default of debtor country. Our empirical specification amongst other is in line with Rahnama-Moghadam (1995) and Balkan (1992). To define a probit model, consider a country \(i\) observed over \(T\) periods of time \(t\), where \(t = 1, ..., T\) and \(i = 1, ..., N\). We think of an unobservable random variable, \(y_{it}^*\), as the underlying latent propensity that an observable binary outcome, \(y_{it}\), will be such that

\[
y_{it} = \begin{cases} 
1 & \text{if } y_{it}^* > 0 \\
0 & \text{otherwise}
\end{cases}
\]

Since we are interested in default occurrence rather than the amount of debt defaulted, the dependent variable (default) is a discrete random variable that takes the value 0 if a country does not default during a given year and 1 if it does.

In our setting, the independent variables may be either continuous or discrete. The dependent variable \(y_{it}^*\) is a function of explanatory variable(s) \(x_{it}\), a constant \(\alpha\) and random error term \(u_{it}\). The probit model used to test our prediction is summarised as:
\[ y_{it}^* = \alpha + \sum_{j=1}^{m} \beta_j x_{jit} + u_{it} \] (2.2.2.1)

where \( y_{it} = 1 \) if country \( i \) has rescheduled or defaulted on its debt payments in year \( t \) and 0 if otherwise, and \( x_{jit} \) is the \( j^{th} \) macroeconomic or political variable of country \( i \) in year \( t \). We interpret the coefficients \( \beta_1, \beta_2, ..., \beta_m \) as the partial derivatives of the probability of default with respect to the independent variables, \( x_{1i}, x_{2i}, ..., x_{mi} \). In this light, given the macroeconomic or political characteristics, \( x_{1i}, x_{2i}, ..., x_{mi} \), the binary response model determines the probability that country \( i \) will default or reschedule its debt, against the alternative that country \( i \) will not. We estimate the model in Stata and code is provided in Appendix (A.1).

2.2.3 Results

The central argument of this paper is that there is a significant relationship between corruption, political risk and sovereign default risk. The analysis will centre on the variables of interest (corruption and political variables). We first report the results (with the marginal effects) of our baseline probit model where we regress default on current explanatory variables. Table (2.7.1.4) reports these findings. Column 1 of Table (2.7.1.4) shows our results when we include external debt-GDP ratio and real GDP growth as control variables. The coefficient on corruption has the expected positive sign and insignificant. The coefficient on political stability is significant at 5%. Using the corresponding marginal effect in column 4 of Table (2.7.1.4), the estimated probability effects of corruption and political stability are 0.028 and 0.025, insignificant at 10% and significant at 5%, respectively. This implies that a unit change in corruption will increase the probability of default by 3%, similarly a unit change in political stability will increase the probability of default by 3%. The model specification in column 2 of Table (2.7.1.4) shows our result when we include external debt-GDP ratio and GDP per Capita as control variables. The coefficient on corruption has the expected positive sign and significant at 10% whilst the coefficient on political stability is positive.
and significant at 5%. Using the corresponding marginal effect in column 5 of Table (2.7.1.4), the estimated probability effects of corruption and political stability are 0.036 and 0.025, significant at 10% and 5%, respectively. This implies that a unit change in corruption will increase the probability of default by 4%, similarly a unit change in political stability will increase the probability of default by 3%. The model specification in column 3 of Table (2.7.1.4) shows our results when we include external debt-GDP ratio, real GDP growth and GDP per Capita as control variables. The coefficient on corruption has the expected positive sign and significant at 10% whilst the coefficient on political stability is positive and significant at 5%. Using the corresponding marginal effect in column 6 of Table (2.7.1.4), the estimated probability effects of corruption and political stability are 0.036 and 0.025, significant at 10% and 5%, respectively. This implies that a unit change in corruption will increase the probability of default by 4%, similarly a unit change in political stability will increase the probability of default by 3%.

The existing empirical literature (see Balkan (1992); Li (1992); Verma (2002); Bordo and Oosterlinck (2005) and Laušev et al. (2011)) on sovereign default and political risks do not distinguish between corruption and political (in)stability. We distinguish between the two in order to investigate the influence that each (corruption and political stability) independently exerts on sovereign default. We find a result that may seem puzzling. We find that the coefficient on corruption is positive in all cases which continues to indicate that higher corruption is associated with a higher sovereign default probability. Also, we observe a positive coefficient for political stability in all cases. It would be generally thought that political instability is conducive to sovereign default but our results indicate otherwise. The reason for the positive effect of political stability on default risk lies in its ability to create room for more borrowing. We therefore argue that the positive sign is consistent with findings in the literature (see Verma (2002); Bordo and Oosterlinck (2005)) that suggest that political stability or democracy has positive influence on sovereign default. Also, the findings from our theoretical model show that higher political stability increases default probability because
the former creates an enabling environment for more borrowing, a mechanism similar
to Hatchondo et al. (2009).

2.2.3.1 Robustness Analyses

We test the sensitivity of our baseline results to other specifications of the model. In
particular, we check for robustness by specifying the model with lagged explanatory
variables and by including lagged dependent variable as an explanatory variable. As
we have argued earlier these specifications with lagged explanatory variables (including
lagged dependent variable) is supported by the literature (see McFadden et al. (1985);
Balkan (1992); Li (1992); Aylward and Thorne (1998); Laušev et al. (2011) and Pestova
(2015)).

Our first check for robustness involves running a probit model of current default
on past explanatory variables. Table (2.7.1.5) reports our findings. Column 1 of Table
(2.7.1.5) shows our result where we include past external debt-GDP ratio and past real
GDP growth as control variables. The result shows that the coefficient on corruption
is positive and significant at 10%. The general conclusion to be drawn is that higher
levels of corruption are associated with greater risks of sovereign default, as our baseline
results suggest. The coefficients on political stability is positive, significant at 1% and
consistent with our baseline results. Using the corresponding marginal effect in column
4 of Table (2.7.1.5), the estimated probability effects of corruption and political stability
are 0.036 and 0.030, significant at 10% and 1%, respectively. This implies that a unit
change in corruption will increase the probability of default by 4%, similarly a unit
change in political stability will increase the probability of default by 3%. In column
2 of Table (2.7.1.5) is our result when we include past external debt-GDP ratio and
past GDP per Capita as control variables. The result shows that the coefficient on
corruption is positive and significant at 10% whilst the coefficient on political stability
is positive, significant at 1% and consistent with our baseline results. By including
past GDP per Capita as a control variable, the effect of past corruption on default is
bigger than when we include past real GDP growth as a control variable. Using the corresponding marginal effect column in 5 of Table (2.7.1.5), the estimated probability effects of corruption and political stability are 0.040 and 0.029, significant at 10% and 1%, respectively. This implies that a unit change in corruption will increase the probability of default by 4%, similarly a unit change in political stability will increase the probability of default by 3%. The result in column 3 of Table (2.7.1.5) displays our findings where we include past external debt-GDP ratio, past real GDP growth and past GDP per Capita as control variables. The result shows that the coefficient on corruption is positive and significant at 5% whilst the coefficient on political stability is positive, significant at 1%. As we include both past real GDP growth and GDP per Capita as a control variables, the effect of past corruption on default increases. Using the corresponding marginal effect column in 6 of Table (2.7.1.5), the estimated probability effects of corruption and political stability are 0.043 and 0.029, significant at 5% and 1%, respectively. This implies that a unit change in corruption will increase the probability of default by 4%, similarly a unit change in political stability will increase the probability of default by 3%.

Finally, we check for robustness by running a probit model of current default on past default and past explanatory variables. The results in Table (2.7.1.6) reports our findings. Column 1 of Table (2.7.1.6) shows our result where we include past default, past external debt-GDP ratio and past real GDP growth as control variables. The result shows that the coefficient on past default is positive and significant at 1% whilst the coefficient on corruption is positive but insignificant. The coefficient on political stability is positive and significant at 5%. Using the corresponding marginal effect column in 4 of Table (2.7.1.6), the estimated probability effects of corruption and political stability are 0.031 and 0.026, insignificant and significant at 5%, respectively. This implies that a unit change in corruption will increase the probability of default by 3%, similarly a unit change in political stability will increase the probability of default by 3%. When we include past default, past external debt-GDP ratio and past GDP per Capita as control variables, as displayed in column 2 of Table (2.7.1.6), the
coefficients on past default and political stability are positive and significant at 1% and 5% respectively whilst the coefficient on corruption is positive but insignificant. Using the corresponding marginal effect column in 5 of Table (2.7.1.6), the estimated probability effects of corruption and political stability are 0.034 and 0.025, insignificant and significant at 5%, respectively. This implies that a unit change in corruption will increase the probability of default by 3%, similarly a unit change in political stability will increase the probability of default by 3%. The result in column 3 of Table (2.7.1.6) displays our findings where we include past default, past external debt-GDP ratio, past real GDP growth and past GDP per Capita as control variables. We find that whilst the coefficients on past default and political stability are positive and significant at 1% and 5% respectively, the coefficient on past corruption is positive and significant at 10%. Using the corresponding marginal effect column in 6 of Table (2.7.1.6), the estimated probability effects of corruption and political stability are 0.038 and 0.025, significant at 10% and 5%, respectively. This implies that a unit change in corruption will increase the probability of default by 4%, similarly a unit change in political stability will increase the probability of default by 3%.

The coefficients on corruption and political stability are positive in all cases, an indication that higher corruption and political stability are associated with a higher sovereign default probability. The general conclusion to be drawn is that this not only implies that there is a positive association with sovereign default and, corruption and political stability, but that there is persistence in this relationship. In particular, past default, corruption, political stability and macroeconomic variables tend to have a significant positive influence on current default—a result which is in line with other findings (see McFadden et al. (1985); Balkan (1992); Li (1992); Aylward and Thorne (1998); Laušev et al. (2011) and Pestova (2015)).

2.2.4 Discussion

Taken together, our results suggest that there is a significant positive association between sovereign default and political risk, controlling for other important determ-
inants of default. This central finding remain fairly robust to a battery of sensitivity analyses, including additional controls and various specifications. However, it should be emphasised that our results do not imply causality. The reason for this is that there could be endogeneity (e.g. measurement issues, simultaneity etc.) in the specifications we adopted above. Unfortunately, the nature of our sample (e.g. emerging markets) and dataset mean that this issue cannot be effectively resolved. The main challenge we face relates to the issue of finding suitable instruments for political risk indicators, including corruption (i.e. institutional quality). Fortunately enough, our model specifications are consistent with many studies (see Balkan (1992); Li (1992); Verma (2002) and Laušev et al. (2011)), on this area, which have not used instruments for institutional variables.

This paper provides empirical evidence about the importance of corruption and political factors on predicting sovereign default probabilities of emerging economies. Emerging economies have become an important investment destination in recent times. Estimating models that can provide sign of sovereign default probabilities would be of interest to investors. Overall, our results show that emerging economies that want to reduce their probabilities of default, the cost of borrowing and improve access to credit, should generally:

1) Control and reduce corruption, attract more Foreign Direct Investments and stimulate GDP growth.

2) Have a good repayment habit by reducing the size of the external debt-GDP ratio and avoid sovereign default on debt resulting from unwillingness rather than inability to repay.

One recommendation for future research concerns the specification of the econometric model itself. We could improve the model by including more specific political risk factors as explanatory variables, such as number of armed conflicts in the country during the sample period and/or the number of political turnovers of the government. Finally, we could include more financial market variables to improve the accuracy of the models.
2.3 The Theoretical Model

We consider an economy with infinitely-lived households and alternating types of government. The basic structure of our model follows that of Eaton and Gersovitz (1981), as used recently by Arellano (2008), Yue (2006), Aguiar and Gopinath (2006) and Hatchondo et al. (2009). Our model differs from those frameworks by incorporating government expenditures and government corruption into the analysis of sovereign default. The theoretical model intends to replicate the main empirical observations.

The basic assumption is that the central government borrows from the international financial market to smooth consumption of households through trading of non-contingent bonds. There is a single tradable good and a stochastic endowment stream of income. The government has an opportunity to default on its debt and thereby avoid making debt repayments. However, doing this is costly as it leads to a loss in output in the following period.

Corruption takes the form of a government’s pilfering of public funds raised through high taxes. There exist two types of political rulers which alternate in power and which differ according to their propensity to be corrupt. Both types are partially benevolent in the sense that they care about the utility of households and also extract corrupt consumption. At the beginning of period a corrupt ruler in power observes the current state of the economy and borrows to smooth consumption of households. During this period, ruler observes the realisations of shocks and the level of debt, and decides whether or not to default. If default is chosen, the economy subsequently suffers an output loss and lower bond prices. At the end of the period, there is an exogenous probability that the ruler will be replaced by the alternative government.

2.3.1 The Government’s Decision Problem

There is a single tradable good in the economy. The economy receives a stochastic endowment $y$, which follows an $AR(1)$ around a long run mean $\mu_y$, and evolves according to
\[
\log(y_t) = (1 - \rho)\mu_y + \rho_y \log(y_{t-1}) + \epsilon_t
\]

\(|\rho_y| < 1, \text{ and } \epsilon_t \sim N(0, \sigma^2_\epsilon)\).

The government finances its budget through taxes on output. In addition to tax income, the government has access to financial assets in the form of one-period non-contingent bonds.

We differ from Cole et al. (1995), Alfaro and Kanczuk (2005), and Hatchondo et al. (2009) in assuming that two types of policymakers with different levels of corruption alternate in power. When in power, the objective of the policymaker is to maximise the present discounted value of future utility flows, on behalf of the households. There is a probability \(\pi_j\) that at the end of every period the type of policymaker in power will change. Unlike Hatchondo et al. (2009), in our model the value of \(\pi_j\) is state dependent, where \(j \in \{L, H\}\) denotes the government type. More corrupt policymakers are able to loot \(c^g_H\) from the state coffers whilst at the same time face a probability of \(\pi_H\) of being replaced. The less corrupt policymakers are able to loot \(c^g_L\) from the state coffers whilst at the same time face a lesser probability of \(\pi_L\) of being replaced, where \(c^g_H > c^g_L\) and \(\pi_H > \pi_L\).

Thus far, this set-up helps compare our model to recent models of political instability and sovereign default, but also illustrates the crucial role played by corruption as a determinant of sovereign default. The policymaker in power determines how much to borrow for the following period and whether to pay back previously issued debt. Financial assets available to the policymaker are in the form of one-period non-contingent bonds. A bond issued in the current period delivers one unit of the good in the next period if no default. At the beginning of the period, the economy has bond position denoted by \(b\). In the previous period if the country was an issuer of bonds, the value of \(b\) is negative.

Following others (see Aguiar and Gopinath (2006); Hatchondo et al. (2009)), we consider defaulting to be costly because it imposes a direct output loss on the economy in the future. This assumption that countries suffer an output loss following a default is meant to capture any disruptions in economic activity resulting from a default decision.
We denote this output loss by $\lambda$ percent\(^2\).

Information on the type of government and the economy’s endowment is perfectly available to lenders. There is a continuum of risk-neutral lenders in the international financial market and lenders can borrow or lend at the risk-free rate $r$. The bond price is determined when the government determines how many bonds to issue and sells to the lender that offers the highest price. We denote as $q_{jd}(y, b')$ the price offered when ruler $j$ issues a total of $-b'$ of bonds. This price depends on whether the country currently has defaulted ($d$), current endowment realisation $y$ and asset choice $b'$ but does not depend on default decisions in previous periods because we assume that the effect of a default on output only lasts for one period and lenders are forward looking. We specify how this price is determined later in Section (2.3.3).

The government’s budget constraint in a given period is summarised by:

$$c + c^d_j + q_{jd}(y, b')b' \leq (1 - h\lambda)y + (1 - d)b$$  \hspace{1cm} (2.3.1.1)

where $c$ is household consumption and $c^d_j$ is ruler $j$’s corrupt consumption. $y$ is output, $b$ is existing assets (negative if borrowing) and $d$ is default. $d = 1$ if the government is defaulting on its existing debt, otherwise it is 0. $h$ is the history of default, where $h = 1$ if the government defaulted in the previous period, and 0 otherwise. $q_{jd}(y, b')$ is the bond price for ruler $j$ in power. This price depends on whether the country currently has defaulted ($d$), current endowment realisation $y$ and asset choice $b'$. Corrupt consumption $c^d_j$ is expressed as:

$$c^d_j = \tau_j(1 - h\lambda)y$$

\(^2\)Some of the earliest papers (see Aguiar and Gopinath (2006)) on sovereign default assumed that $\lambda$ is the output lost in autarky given that a country is excluded from the financial market after default for stochastic number of periods. Rose (2005) finds evidence that following the initiation of debt renegotiation by a country, bilateral trade flows declines by 8% a year. However, some recent papers such as Hatchondo et al. (2007), Hatchondo et al. (007a), and Hatchondo et al. (2009) that assume non-exclusion from the financial market, argue that output loss occurs period after default. They argue generally that the assumption of output-loss after default decision is meant to capture any disruptions in economic activity that will be caused by a default. They posit further that a sovereign default decreases private sector financing and will thus reduce aggregate output. Also as argued in Hatchondo et al. (2007) whether we specify the output loss to be stochastic or only one period after default would not make difference. However, we assume in our model it follows the period after default for simplicity reasons.
where $\tau_j$ is the tax rate of ruler $j$. This assumption of the tax rate being affected by corruption is grounded in public capital and corruption, and tax avoidance and corruption literature (see Chen (2003); Coppier et al. (2006); Ellis and Fender (2006); Attila (2008)). The specification is to capture the effect of corruption consumption, borrowing and welfare, through taxation and corrupt consumption.

The ruler in power uses the available resources, after corrupt consumption, to maximise life time utility subject to Equation (2.3.1.1), by choosing $c$ and $b'$. Flow utility of government $j$ is CRRA utility $u(c) = \frac{c^{1-\varphi} - 1}{1-\varphi}$, where $\varphi$ is the risk aversion parameter.

At the beginning of the period ruler $j$ in power observes the economy’s endowment realisation and accordingly makes a default decision on previously issued debt. The ruler issues an amount $-b'_{j0}(b, y, h)$ of bonds if the decision is not to default. Otherwise, the ruler issues an amount $-b'_{j1}(y, h)$ of bonds. The type of ruler in power changes with a probability of turnover rate $\pi_j$ or otherwise sticks to power at the rate $(1 - \pi_j)$, before the next period. In our setting, the probability of turnover is allowed to depend on the type of government in power. In light of this, the more corrupt ruler faces an economy with higher political instability than the less corrupt ruler. As stated earlier, in the follow-up period after a default, the economy suffers an output loss of $\lambda$ percent.

Ruler $j$ in power compares the value functions $V_{j1}(y, h)$, if a default is declared in the current period and $V_{j0}(b, y, h)$, if a default is not declared in the current period; where $y$ is the current endowment realisation, and $h$ the credit history.

### 2.3.2 Solution

We use the value function iteration method to solve the dynamic problem. Let $V_j(y, b, h)$ denote the value function of a government of type $j$ at the beginning of period $t$ when in power. Similarly, let $\tilde{V}_j(y, b, h)$ denote the value function of a government of type $j$ at the beginning of period $t$ when it is not in power. Finally, let $\pi_j$ denote the probability of political turnover of a government of type $j$. When deciding whether to default, the government in power compares two continuation values, $V_{j1}(y, h)$ and $V_{j0}(y, b, h)$. 
The value of a type-j government of defaulting in the current period is given by:

\[
V_{j1}(y, h) = \max_{c, b'} \left\{ u(c) + \beta \mathbb{E}[\pi_j \hat{V}_j(y', b', 1) + (1 - \pi_j)V_j(y', b', 1)|y]\right\}
\]  

subject to

\[
c + c^g_j + q_{j1}(y, b')b' = (1 - h\lambda)y
\]

where \(c^g_j = \tau_j(1 - h\lambda)y\)

Since the government is defaulting, \(d = 1\) in Equation (2.3.1.1). The government then chooses \(c\) and \(b'\) subject to this budget constraint. The associated policy functions are \(c_{j1}(y, h)\) and \(b'_{j1}(y, h)\).

The value of a type-j government of not defaulting in the current period is given by:

\[
V_{j0}(y, b, h) = \max_{c, b'} \left\{ u(c) + \beta \mathbb{E}[\pi_j \hat{V}_j(y', b', 0) + (1 - \pi_j)V_j(y', b', 0)|y]\right\}
\]  

subject to

\[
c + c^g_j + q_{j0}(y, b')b' = (1 - h\lambda)y + b
\]

where \(c^g_j = \tau_j(1 - h\lambda)y\)

Since the government is not defaulting, \(d = 0\) in Equation (2.3.1.1). The government then chooses \(c\) and \(b'\) subject to this budget constraint. The associated policy functions are \(c_{j0}(y, b, h)\) and \(b'_{j0}(y, b, h)\).

The value function of the government in power, \(V_j(y, b, h)\) is then computed as follows:

\[
V_j(y, b, h) = \max(V_{j1}(y, h), V_{j0}(y, b, h))
\]  

where \(d = 1\) if \(V_{j1}(y, h) \geq V_{j0}(y, b, h)\) (government defaults). Otherwise \(d = 0\). Let \(d_j(y, b, h)\) denote the associated policy function.
\[
d_j(y, b, h) = \begin{cases} 
1 & \text{if } V_{j1}(y, h) \geq V_{j0}(y, b, h) \\
0 & \text{if } V_{j1}(y, h) < V_{j0}(y, b, h) 
\end{cases}
\tag{2.3.2.4}
\]

Remaining policy functions are:

\[
c_j(y, b, h) = \begin{cases} 
c_{j1}(y, h) & \text{if } d_j(y, b, h) = 1 \\
c_{j0}(y, b, h) & \text{if } d_j(y, b, h) = 0 
\end{cases}
\]

\[
b'_j(y, b, h) = \begin{cases} 
b'_{j1}(y, h) & \text{if } d_j(y, b, h) = 1 \\
b'_{j0}(y, b, h) & \text{if } d_j(y, b, h) = 0 
\end{cases}
\]

The value function of government of type \( j \) when it is not in power depends on the optimal behaviour of the other government, denoted by \( -j \). The value of a policymaker of type \( j \) when it is not in power can be more concisely written as:

\[
\hat{V}_j(y, b, h) = u(c_{-j}(y, b, h)) + \beta E[\pi_{-j}V_j(y', b'_{-j}(y, b, h), d_{-j}(y, b, h)) + (1 - \pi_{-j})\hat{V}_j(y', b'_{-j}(y, b, h), d_{-j}(y, b, h)) | y]
\tag{2.3.2.5}
\]

When policymaker \( j \) is not in power, it receives no corrupt consumption, but it still derives utility from household consumption (which is chosen by the other policymaker). Next period, with probability \( \pi_{-j} \), policymaker \( j \) will become the government in power, in which case it’s initial state will depend on the actions of the current government. With probability \( 1 - \pi_{-j} \), policymaker \( j \) will still be out of power. In that case, its state is still determined by the actions of the government in power.

\textit{2.3.3 Bond Price}

We define \( p_j^{def}(y, b', h') \) to be the probability that the type-\( j \) government (if it is in power next period) will default on the debt \( b' \) tomorrow with history \( h' \) given current endowment realisation \( y \).

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\[ p_{j}^{def}(y, b', h') = \int d_j(y', b', h') f(y' | y) dy' \]

where \( f(y' | y) \) is the probability density function for \( y' \).

The bond price \( q_{jd}(y, b') \) satisfies the lender’s zero-profit condition.

\[ q_{jd}(y, b') = \frac{1}{1 + r} [1 - \pi_j p_{-j}^{def} (y, b', d) - (1 - \pi_j) p_j^{def} (y, b', d) ] \quad (2.3.3.1) \]

Bond prices today depend on the credit history the future government will inherit (\( h' \)) because defaulting in the current period reduces future output. The credit history \( h' \) just reflects the current default decision (i.e. \( h' = d \)). This price \( q_{jd}(y, b') \) reflects two things. First, with probability \( \pi_j \), the other government will be in power and it will default with probability \( p_{-j}^{def} (y, b', d) \). However, with probability \( (1 - \pi_j) \), the current government will remain in power, and it will default with probability \( p_j^{def} (y, b', d) \).

2.3.4 Equilibrium

Governments act sequentially when choosing current levels of taxes, corrupt consumption and debt with foresight. Drawing on the works of Krusell and Smith Jr (2003), Klein et al. (2008), and Ortigueira et al. (2012) we will concentrate on differentiable Markov-perfect equilibria of this economy. However, as it is shown in Krusell and Smith Jr (2003) there is a problem of indeterminacy of Markov-perfect equilibria in an economy with infinite horizon. Hatchondo et al. (2009) argue that the problem is avoided analysing the equilibrium that arises as the limit of the finite-horizon economy equilibrium.

A Markov-perfect equilibrium is defined as:

(1) the set of value functions \( V_j(y, b, h), V_{j0}(y, b, h), V_{j1}(y, h) \) and \( \hat{V}_j(y, b, h) \) for all \( j = L, H \)

(2) the policy functions \( c_{j0}, c_{j1}, b_{j0}'(y, b, h), b_{j1}'(y, h) \) and the default decision rule \( d_j(y, b, h) \) for all \( j = L, H \)
(3) and the bond price $q_{jd}(y, b')$ for all $j = L, H$,
such that

(a) the value functions $V_j(y, b, h)$, $V_{j0}(y, b, h)$, $V_{j1}(y, h)$ and $\hat{V}_j(y, b, h)$ satisfy the functional Equations in (2.3.2.1), (2.3.2.2), (2.3.2.3), (2.3.2.4), (2.3.2.5) and (2.3.3.1).

(b) the policy functions $c_{j0}$, $c_{j1}$, $b'_{j0}(y, b, h)$, $b'_{j1}(y, h)$ and $d_j(y, b, h)$ solve the dynamic programming problem specified in Equations (2.3.2.1), (2.3.2.2), (2.3.2.3), (2.3.2.4), (2.3.2.5) and (2.3.3.1).

(c) the bond price $q_{jd}(y, b')$ satisfies the lenders’ zero profit condition in Equation\(^3\) (2.3.3.1).

2.4 Results

We show that all defaults may be strategic. In addition, we find that in the presence of corruption and political turnover, the model performs better in many ways. First, the model is able to generate the moderate correlation between output and default decisions as it is documented by Tomz and Wright (2007), the latter also influenced by the level of corruption. Second, the model helps in generating lower issuance levels after a default episode. Third, the model is able to generate higher but volatile spreads. Overall, both corruption and political turnover are important in order for the model to generate higher credit spreads, higher default rates and more volatile interest rates.

2.4.1 Calibration

We solve the model using value function iteration in Fortran 90 (see Appendix (2.6) for details and Appendix (A.1) for the codes). We calibrate the model to match a typical emerging economy that is known for corruption and also has history of sovereign default. Our calibration is summarised in Table (2.4.1.1) and most calibrated parameters are based on Hatchondo et al. (2009). The output loss parameter associated with default is taken to be 8.3%. The risk-free interest rate is set at 1% whilst we

\(^3\)As in the literature (see Hatchondo et al. (2007); Hatchondo et al. (2009)), we assume the risk-free interest rate is such that $\beta(1 + r) < 1$. 

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choose a discount factor of 0.90 equal to the discount factor used by Hatchondo et al. (2009) for a patient type, and greater than the discount factor (0.80) used by Aguiar and Gopinath (2006).

We calibrate the tax rates of the less corrupt and more corrupt rulers to be 22% and 50%, respectively. In our case, the degree of political stability is state dependent (unlike Hatchondo et al. (2009)), and as such, varies with the level of corruption. The more corrupt government stays in power for an average duration of 4 years and 3 years, respectively, under stable and unstable economies. On the other hand, the less corrupt government stays in power for an average duration of 8 years and 6 years, respectively, under stable and unstable economies.

2.4.2 Corruption, Political Risk and Default Risk

Our first line of inquiry concerns the question of whether changes in the political environment associated with changes in the level of corruption can trigger sovereign default. Cole et al. (1995); Alfaro and Kanczuk (2005); Hatchondo et al. (2009) show that political circumstances can trigger sovereign default. Hatchondo et al. (2009) argue that sovereign default is likely to be caused by political turnover\footnote{Government turnover rate is the probability with which a government is replaced. Political/Government stability on the other hand, is how big or small a turnover rate is. For instance a smaller turnover rate will mean more stability. In the extreme case 0 will mean no turnover but most stability.} if there enough political stability in the economy. We add to their findings by showing that corruption could be a trigger for sovereign default not only when there is political turnover but without political turnover. We simulate the model for 1,500,000 periods (1,000 samples of 1,500 observations each) using the calibrations in Table (2.4.1.1) in order to show our results.

We show that when there is political stability but a possibility of political turnover, a change in regime from a less corrupt government to a more corrupt government is more likely to trigger default than a change in regime from a more corrupt government to a less corrupt government. In the economy with high political stability, changes from
<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Aversion</td>
<td>$\varphi$</td>
<td>2</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>$r$</td>
<td>1%</td>
</tr>
<tr>
<td>Autocorrelation Coefficient</td>
<td>$\rho_y$</td>
<td>0.95</td>
</tr>
<tr>
<td>Standard Dev of Innovations</td>
<td>$\sigma_z$</td>
<td>2.7%</td>
</tr>
<tr>
<td>Output Loss</td>
<td>$\lambda$</td>
<td>8.3%</td>
</tr>
<tr>
<td>Discount Factor</td>
<td>$\beta$</td>
<td>0.90</td>
</tr>
<tr>
<td>Mean (Log) Output</td>
<td>$\mu_y$</td>
<td>$-\frac{1}{2}\sigma_z^2$</td>
</tr>
<tr>
<td>Tax Rate of Less Corrupt Government</td>
<td>$\tau_L$</td>
<td>22%</td>
</tr>
<tr>
<td>Tax Rate of More Corrupt Government</td>
<td>$\tau_H$</td>
<td>50%</td>
</tr>
<tr>
<td>Stable Economy’s Turnover Rate for Less Corrupt Government</td>
<td>$\pi_L^s$</td>
<td>3.1%</td>
</tr>
<tr>
<td>Unstable Economy’s Turnover Rate for Less Corrupt Government</td>
<td>$\pi_L^u$</td>
<td>4.4%</td>
</tr>
<tr>
<td>Stable Economy’s Turnover Rate for More Corrupt Government</td>
<td>$\pi_H^s$</td>
<td>7.0%</td>
</tr>
<tr>
<td>Unstable Economy’s Turnover Rate for More Corrupt Government</td>
<td>$\pi_H^u$</td>
<td>10%</td>
</tr>
</tbody>
</table>
a less corrupt to a more corrupt government triggers default 95.5% of the time, whereas
in an unstable economy, default happens only 2% of the time (see Table (2.7.1.7)). In
the stable economy, it is more likely that the less corrupt policy maker will choose high
debt levels which would lead to a more corrupt policy maker to default.

We have to make certain specific assumptions about certain variables in order to
be able to present some of our results in two-dimensional charts. However, the results
will not change much under alternative assumptions.

There are combinations of debt levels and endowment realisations at which a
more corrupt type defaults and a less corrupt type does not default. For a combina-
tions of debt levels and endowment realisations where the less corrupt type chooses to
default, the more corrupt type will also choose to default. Figure (2.4.2.1) depicts the
value of default and the value of not defaulting for the less corrupt and more corrupt
governments. The value of default does not depend on debt, and is therefore depicted
by horizontal lines, because initial debt becomes zero after a government defaults. The
upward sloping curves depict the expected utility of both governments. They show
that the expected utility decreases with debt when governments do not default. The
line depicting the value of not defaulting for the less corrupt government lies above
the line depicting the value of not defaulting for the more corrupt government. This
implies that there are debt levels (between 0.06 and 0.098) at which the more corrupt
government defaults and less corrupt government does not.
Figure 2.4.2.1.: Value functions in a stable economy under less and more corrupt governments. The figure assumes the case where the endowment realisation coincides with unconditional mean of its distribution, and where the government inherits a good credit history ($h = 0$).

The optimal default decision of the two types of government is also illustrated in Figure (2.4.2.2). Figure (2.4.2.2) plots default space against debt and endowment realisation for more corrupt and less corrupt governments. The dark area shows combinations of bond positions and endowment realisations at which a more corrupt government defaults and a less corrupt government does not default. The grey area shows combinations of bond positions and endowment realisations at which both types default. The white area shows combinations of bond positions and endowment realisations at which neither the less corrupt nor the more corrupt government will default. It shows that default is more likely with more debt and lower endowment realisations. That is for any given level of corruption and endowment realisation, the risk of default is
greater with more debt. Similarly, for any given level of debt and corruption, any type of government is more likely to default when endowment realisation is low than when endowment realisation is high. The figure shows that the risk of default is greater with more corruption; at the same level of debt and endowment realisation, default risk is higher with more corruption.

**Figure 2.4.2.2.:** Default space against bond issuance and endowment for less and more corrupt governments, where they inherit a good credit history ($h = 0$).

This implies that a more corrupt government is more likely to default on lower level of debt than a less corrupt government will do. Given enough political stability, the less corrupt policymaker borrows more and the more corrupt policymaker defaults upon assumption of office. Another reason is that low corruption reduces government consumption and this in turn increases private consumption. On the other hand, high corruption leaves less resources for private consumption and the government has a
greater incentive to default and keep the money for itself.

The shape of the bond price function that a government in power faces is affected by the optimal default strategies of types. Figure (2.4.2.3) presents a plot of the bond price for less corrupt government under stable and unstable economies, and the economy without political turnover. The bond price received by the government for bonds issued is affected by the probability of default the following period, the level of corruption and the political turnover of the government. As a result, the bond price functions in economies with political turnover shows three steps. Drawing from Hatchondo et al. (2009), the right step shows “low” issuance region, where debt issued is so low that any type of government will surely pay back the following period. Due to the less risky nature of debt in this region, investor charge the risk-free rate which results in high bond prices. The middle step shows the “intermediate” issuance region. In this region, the more corrupt type would default in the following period if he comes into power, whilst the less corrupt type will choose to pay the debt back if he remains in power. In this region lenders charge positive spread which depends on the turnover rate (which is dependent on the government type). This is to say that the more corrupt government is charged higher spreads than the less corrupt government, for instance, in a politically stable economy. For a given level of corruption, the spread is higher in the unstable economy than the stable economy. However, the higher the level of corruption the higher the spread for each type of economy.

The third step is the “high” issuance region, where both types will default next period when in power. Consequently, lenders offer low price for bonds issued in this region. Figure (2.4.2.3) shows that in the “intermediate” region of issuance the better the price, the more politically stable the economy is. With chances that the more corrupt assumes power the following period and declares default, the less corrupt government issuing bonds in this region would have to compensate lenders for default contingency. An increase in the probability of this contingency results in a decrease in bond price in the “intermediate” region and the vice versa. The bond price does not feature the “intermediate” step where there is no turnover and only the less corrupt government
remains in power.

Figure 2.4.2.3.: Bond price for less corrupt government (τ_L) in stable and unstable economies and in economies without political turnover. The figure assumes the case where the government has not defaulted today and the endowment realisation corresponds with the unconditional mean of its distribution.

Figure (2.4.2.4) is a plot of objective function of the less corrupt government as a function of bond issuance. The shape of this objective function of the government is related to the shape of the bond price function discussed above. Just as in the bond price function, the objective function increases at “low” issuance levels, whilst in transition to the second step from the first step of the bond price function, it decreases. This accounts for the right local maxima. The objective function begins to increase again once the second step of the bond price function is reached. As the “high” bond issuance region of the bond price function is reached, the objective function begins to decline and remain low, which explains the left local maxima. As explained in
Hatchondo et al. (2009) the increasing portions of the objective function are as a result of the differences between the rate at which future utility flows are discounted and the interest rate, whilst the decreasing portions are explained by the decline in bond price as a result of increasing issuance levels. In the politically stable economy, the optimal borrowing level may occur at the left local maximum, whilst in the politically unstable economy the optimal borrowing levels may occur at the right local maximum. The optimal borrowing levels of the less corrupt policymaker in the politically stable economy is higher and attractive than in the politically unstable economy because as instability decreases, the less policymaker is charged a lower spread by lenders. This low spread in a politically stable economy might induce less corrupt policymakers to choose borrowing levels in the intermediate region which then makes default more likely when there is change in power to the more corrupt policymaker.

The results in Table (2.4.6.2) displays the expected probabilities of default. It is observed that, in the stable economy, the probability of default given that the less corrupt government in power today$^{5}$ is about 11.13%, whereas the probability of default given that the more corrupt government in power today is about 0.44%. However, in the politically unstable economy, the probability of default given that the less corrupt government in power today is about 0.32%, while the probability of default given that the more corrupt government in power today is about 0.48%. Similarly, in the politically stable economy, the average number of defaults given that the less corrupt government is in power today is about 0.20%, while the average number of defaults given that the more corrupt government in power today is about 0.84%. In the politically unstable economy, however, the average number of defaults given that the less corrupt government is in power today is about 0%, while the average number of defaults given that the more corrupt government in power today is about 0.48%. Overall, the higher credit spreads faced by the low type in the stable economy reflect the probability that the high type will come into power next period and default.

---

$^{5}$This probability takes into account the possibility that the more corrupt government might be in power tomorrow, but also that the less corrupt government will most likely still be in power tomorrow.
Objective function when $\pi^s_L = 3.1\%$

Objective function when $\pi^u_L = 4.4\%$

Figure 2.4.2.4.: Objective function of a less corrupt government ($\tau_L$) in the stable and unstable economies. The figure assumes the case where the government has chosen not to default and the endowment realisation corresponds with the unconditional mean of its distribution, and where the government inherits a good credit history ($h = 0$).

Figure (2.4.2.5) shows that a less corrupt policymaker chooses intermediate borrowing levels if it encounters intermediate endowment realisations. The right end of the graph is where the endowment realisation is at its highest and where the less corrupt policymaker chooses low borrowing level. In other words, when a less corrupt policymaker faces good economic conditions, political turnover might not trigger default. The left end of the graph is where the endowment realisation is at its lowest and where both types of policymakers are likely to default when in power. As the policymaker defaults and resets its debt level to zero in this low endowment region, it then borrows less because it has low borrowing needs.
2.4.3 Corruption, Welfare and Consumption

Corruption in our model has important implications for welfare and consumption of the households. We show that corruption has the propensity to negatively affect the welfare and consumption of the households. Following the seminal work of Lucas (1987), we estimate welfare loss (consumption equivalent) as the percentage decrease in consumption in the non-corrupt economy which makes households indifferent between the corrupt economy and the non-corrupt economy. Table (2.4.3.1) shows the average household consumption equivalent welfare loss (in percentage terms) for the less and more corrupt (see Appendix (3.5.5) for detailed derivation of welfare loss). Again, the results indicate that welfare loss increases with the level of corruption. In other
words, the results show how much households are willing to pay (and this amount is more when a more corrupt policymaker is in office) in order to have corruption-free consumption. On the whole, the results show that households are willing to give up (43%) of consumption in the non-corrupt economy when a more corrupt policymaker is in office and (28%) of consumption in the non-corrupt economy when a less corrupt policymaker is in office, in order to have corruption-free consumption.

Table 2.4.3.1.: Average Consumption Equivalent Welfare Loss

<table>
<thead>
<tr>
<th>Level of Corruption</th>
<th>Consumption Equivalent Welfare Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau_L$</td>
<td>28%</td>
</tr>
<tr>
<td>$\tau_H$</td>
<td>43%</td>
</tr>
</tbody>
</table>

2.4.4 Characteristics of Debt and Spread around Defaults

We define two types of defaults. The first is a “non-political default”, which is any default that is not triggered by a change in government. The second, “political default”, are all the defaults which are triggered by a change in government (see Hatchondo et al. (2009)). It is argued that during political default, post-default issuance levels are lower than pre-default issuance levels, whilst in a non-political default there are no differences between pre-default and post-default issuance levels (see Hatchondo et al. (2009)). We show results that are consistent with the literature. Figure (2.4.4.1) shows the differences between pre-default issuance levels and post-default issuance levels under political and non-political defaults.

Hatchondo et al. (2009) find that if the same government remains in power after a non-political default, there should not be difference between pre-default and post-default issuance levels. We find a similar result. We argue that once the type of borrower (less corrupt government or more corrupt governments) does not change and is common knowledge to lenders, there is no need to charge different (higher) spreads which then results in no change in issuance levels. Around political defaults, however, we find that post-default issuance levels are lower than pre-default issuance levels. We argue that as the less corrupt government (whose optimal borrowing is in the intermediate region) is replaced by the more corrupt government (whose optimal borrowing
should be the low issuance region as discussed earlier), post-default issuance levels will be lower than pre-default issuance levels. As the next policymaker (more corrupt) prefers to borrow in the low issuance region, we expect lenders to charge low spreads in the period immediately following a default.

Figure 2.4.4.1.: Average issuance level before and after a default episode in an economy with high political stability. The default period is 0. Political defaults are where less corrupt government is replace by more corrupt government, and non-political defaults are where only a less corrupt government is in power.

Figure (2.4.4.2) shows why more corrupt policymaker might choose lower issuance volumes. The bond price faced by the more corrupt depicts three steps just as the less corrupt policymaker. If a more corrupt policymaker is in office today, it is very likely the next policymaker will also be more corrupt. Following our previous assertion that the more corrupt policymaker defaults at intermediate debt levels, lenders charge high spread for intermediate borrowing levels. This accordingly, explains why the bond
price in the intermediate region is close to zero. Bond price in the low issuance region is higher than that in the intermediate region which explains why the more corrupt policymaker will borrow in the low issuance region.

![Figure 2.4.4.2](image)

**Figure 2.4.4.2.** Bond price faced by a more corrupt government ($\tau_H$) in the stable and unstable economies. The figure assumes the case where the government has defaulted today and the endowment realisation corresponds with the unconditional mean of its distribution.

Figure (2.4.4.3) shows plots of pre-default and post-default average spread levels. In political default, post-default spreads are lower than pre-default spreads. Less corrupt policymakers choose intermediate borrowing levels before political default, and as a result are charged intermediate spreads. The more corrupt replaces the less corrupt and after a default is declared the more corrupt borrows in the low issuance region and lenders respond by charging low spreads in the period immediately following a default. However, if default is non-political, post-default spreads are not different than
pre-default spreads because as the type of government does not change, lenders do not see the need to charge different spreads for the two periods.

![Figure 2.4.4.3: Average spread before and after a default episode in an economy with high political stability. The default period is 0. Political defaults are where less corrupt government is replace by more corrupt government, and non-political defaults are where only a less corrupt government is in power.]

2.4.5 Output and Default

Tomz and Wright (2007) in their studies using data set with 169 default cases, report that 38% of default episodes in their sample occurred in years when the output level in the defaulting country was above the trend value. However, the inability to replicate the weak correlation observed in the data, they argue is as a result of the absence of turnover in their baseline model. To illustrate this, Hatchondo et al. (2009) report that only 3% and 7% of default episodes occur where all policymakers are patient and impatient respectively, in periods where the output level is above its long-run mean and
when there is no turnover. Table (2.4.5.1) illustrates our findings. We find that only 6% of defaults episodes occur in periods where the output level is above its long-run mean when all policymakers are less corrupt. This percentage decreases to 5.3% when all policymakers are more corrupt.

Introducing political turnover into their model, Hatchondo et al. (2009) find that in an economy with high political stability, 38% of default episodes occur in periods where output is above its long-run mean and this decreases to 7% in an unstable political economy. We find that in a politically stable economy when less corrupt policymakers are in power, 3.57% of defaults episodes occur in periods where the output level is above its long-run mean. This increases to 46.85% when more corrupt policymakers are in power. In politically unstable economy when less corrupt policymakers are in power, we find that 0% of defaults episodes occur in periods where the output level is above its long-run mean. This percentage increases to 7.45% when more corrupt policymakers are in power. Overall, we find that in a stable political economy, 45.93% of default episodes occur in periods where output is above its long-run mean and this decreases to 7.45% in an unstable political economy.

<table>
<thead>
<tr>
<th>( \pi_s )</th>
<th>( \pi_u )</th>
<th>( \pi_L ) only</th>
<th>( \pi_H ) only</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.00%</td>
<td>5.30%</td>
<td>3.57%</td>
<td>46.85%</td>
</tr>
<tr>
<td>All Stable</td>
<td>All Unstable</td>
<td>( \pi_L = 3.1% )</td>
<td>( \pi_H = 7.0% )</td>
</tr>
<tr>
<td>0.00%</td>
<td>7.45%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \pi_L = 4.4% )</td>
<td>( \pi_H = 10% )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Default episodes that occur when output is above its long-run mean.

2.4.6 Corruption, Political Turnover and Business Cycle Statistics

We now look at the implications of corruption for business cycles in the economy. Most studies of sovereign default place emphasis on the ability of quantitative sovereign default model to replicate the macroeconomic characteristics of emerging economies before a default. We discuss how the predictions of our baseline model change when we introduce political turnover. To show this, we simulate economies without turnover–where the type of policymaker in power does not change (i.e. \( \pi = 0 \))–and compare these simulations with economies with political turnover (i.e. \( \pi > 0 \)).
To compare quarterly simulated data to that of Nigeria for the period 1993Q1-2000Q4, we simulate the model for 1,000 samples each with 1,500 observations (quarters). Nigeria is used as a benchmark because of its long history of corruption and political disturbance. In addition, Nigeria has reportedly defaulted as many as five times\(^6\) (in 1982, 1986, 1992, 2001 and 2004). We compare data from this period with data from simulation samples where only less corrupt policymakers are in power. Additionally, we also show simulation results for an economy with only more corrupt policymakers. Further, we present simulation results with political turnover and extract the first 1,000 samples with 32 quarters, when the type of government in power is either the less corrupt or the more corrupt. Finally, we present unconditional results using the first 1000 samples with 32 quarters without imposing any restriction on the type of policymakers in power.

High, volatile, and countercyclical interest rates; highly volatile relative consumption; countercyclical net exports are some of the stylised facts of emerging economies. Table (2.4.6.1) documents our results. We present trade balance as a fraction of output \(TB/Y\), annual interest rate spread \(R_s\), logarithm of income \((y)\), logarithm of consumption \((c)\), mean probability of default \(Pr(D)\), mean number of defaults \(E(D)\) and average spread \(E(R_s)\). We HP filter all series with a quarterly smoothing parameter, 1,600. Standard deviations denoted by \(\sigma\) are reported in percentages. We denote correlations by \(\rho\). The second column of Table (2.4.6.1) shows the moments in the data. In the third column of the table we present the average business cycle moments in an economy with only less corrupt policymakers, whilst in the fourth column we present average moments in an economy with only more corrupt policymakers. In the fifth column are the average business cycle moments under a less corrupt policymaker in a stable economy with turnover rate of \(\pi_L = 3.1\%\). The sixth column reports the average business cycle moments under a less corrupt policymaker in an unstable economy.

with turnover rate of $\pi_L^u = 4.4\%$. Finally, the seventh and eighth columns display the unconditional average business cycle moments in a stable economy and an unstable economy, respectively.

The moments of the data as reported in Table (2.4.6.1) display the striking features of a developing economy like Nigeria: counter-cyclicality of net exports (-0.21) and interest rate spreads (-0.64); and the pro-cyclicality of consumption (0.15). Another striking feature of the business cycles of Nigeria as displayed in the data is the high volatility of output (1.40%), consumption (5.60%) and interest rate spreads (11.62%), which are typical stylised facts of developing economies. In particular, these features about interest rate spreads including their high volatility have been observed by others including Perri and Neumeyer (2004) to be true for many emerging economies.

In the presence of political turnover and corruption, the ability of the model to generate high spreads is improved. The average spread observed when less corrupt policymaker is in office in the politically stable economy is 12.86%, compared with 0.37% in the politically unstable economy. When we compare this to the case when only less corrupt policymakers are in office, the average spread is 0.33%. As we argued above, in the politically stable economy, the less corrupt optimally will borrow in the high issuance region which leads to default when the more corrupt policymaker takes office. Consequently, lenders charge the less corrupt higher spreads in the politically stable economy than in the politically unstable economy.

In the stable economy, average spread observed by the less corrupt policymaker (12.86%) is higher than the average spread observed by the less corrupt policymaker (0.33%) and the more corrupt policymaker (0.33%), when political turnover is absent. In the economy where all governments are less corrupt, the average spread is 0.33%. Similarly, in the economy where all governments are more corrupt, the average spread is 0.33%. Corruption and political turnover act as the mechanism through which the model generates a higher average spread. In the model, political turnover amplifies the effect of corruption because with a low turnover rate, less corrupt governments are willing to pay the premium for the possibility that a more corrupt government
Table 2.4.6.1.: Business Cycle Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Data</th>
<th>No Turnover</th>
<th>No Turnover</th>
<th>Stable</th>
<th>Unstable</th>
<th>Stable</th>
<th>Unstable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\tau_L$ only</td>
<td>$\tau_H$ only</td>
<td>$\tau_L$</td>
<td>$\tau_L$</td>
<td>Unconditional</td>
<td>Unconditional</td>
</tr>
<tr>
<td>$\sigma(y)$</td>
<td>1.40</td>
<td>3.18</td>
<td>3.18</td>
<td>3.16</td>
<td>3.15</td>
<td>3.18</td>
<td>3.18</td>
</tr>
<tr>
<td>$\sigma(c)$</td>
<td>5.60</td>
<td>3.27</td>
<td>3.27</td>
<td>3.23</td>
<td>3.20</td>
<td>8.25</td>
<td>9.65</td>
</tr>
<tr>
<td>$\sigma(TB/Y)$</td>
<td>0.60</td>
<td>0.15</td>
<td>0.1</td>
<td>0.16</td>
<td>0.11</td>
<td>0.33</td>
<td>0.11</td>
</tr>
<tr>
<td>$\sigma(Rs)$</td>
<td>11.62</td>
<td>0.18</td>
<td>0.17</td>
<td>0.47</td>
<td>0.32</td>
<td>2.02</td>
<td>0.26</td>
</tr>
<tr>
<td>$\rho(c,y)$</td>
<td>0.15</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.34</td>
<td>0.31</td>
</tr>
<tr>
<td>$\rho(TB/Y,y)$</td>
<td>-0.21</td>
<td>-0.36</td>
<td>-0.36</td>
<td>-0.28</td>
<td>-0.27</td>
<td>-0.11</td>
<td>-0.26</td>
</tr>
<tr>
<td>$\rho(Rs,y)$</td>
<td>-0.64</td>
<td>-0.1</td>
<td>-0.09</td>
<td>-0.15</td>
<td>-0.14</td>
<td>-0.06</td>
<td>-0.07</td>
</tr>
<tr>
<td>$\rho(Rs,TB/Y)$</td>
<td>0.10</td>
<td>-0.04</td>
<td>-0.10</td>
<td>-0.12</td>
<td>-0.17</td>
<td>-0.05</td>
<td>-0.09</td>
</tr>
<tr>
<td>$E(Rs)$</td>
<td>9.60</td>
<td>0.33</td>
<td>0.33</td>
<td>12.86</td>
<td>0.37</td>
<td>6.69</td>
<td>0.37</td>
</tr>
<tr>
<td>$E(D)$</td>
<td>-</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
<td>0.00</td>
<td>5.91</td>
<td>0.28</td>
</tr>
<tr>
<td>$Pr(D)$</td>
<td>-</td>
<td>0.32</td>
<td>0.33</td>
<td>11.13</td>
<td>0.32</td>
<td>5.82</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Moments from the model are averages using 1,000 samples of 32 periods each.
In column two we use data for Nigeria from 1993Q1-2000Q4.
Except correlation coefficients, all statistics are in percentages.
$E(D)$ is mean number of defaults per annum.
$Pr(D)$ is mean probability of default per annum.
Average spread, $E(Rs)$ and volatility of spread, $\sigma(Rs)$ are per annum.
Rest of statistics are quarterly.
will default. Also, political turnover impacts on the ability of the model to generate a higher average spread because it smooths out the bond price function Hatchondo et al. (2009).

The smoother bond price function results in a larger increase in the issuance level when there is a decrease in the bond price. Given that corrupt policymakers have the incentive to issue more debt, lower bond prices make it attractive for them to do so and pay a higher spread. Tables (2.4.6.1) and (2.4.6.2), display the non-monotonic relationship between the degree of political stability and both the average spread and default probability. Starting with column 3 in Table (2.4.6.1), where a less corrupt policymaker is in power in the first period and where turnover is absent; i.e. $\pi = 0$, an increase in the turnover rate to $\pi^L = 3.1\%$ increases the average spread from 0.33\% to 12.86\%. The average spread decreases to 0.37\% when turnover rate increases to $\pi^U = 4.4\%$. Similarly, starting with the case of no turnover in Table (2.4.6.2), an increase in the turnover rate to $\pi^L = 3.1\%$ increases the average probability of default from 0.32\% to 11.13\% which decreases to 0.32\% when turnover rate increases to $\pi^U = 4.4\%$. Does it mean that default is likely to occur in an unstable economy and under more corrupt policymakers? Using the average spreads discussed above as a proxy for default, the answer will likely be no. The average spreads and probabilities of default in Tables (2.4.6.1) and (2.4.6.2) appear to be higher in the politically stable economy than in the politically unstable economy. In the stable economy, less corrupt governments pay high spreads than in the unstable case, despite the fact they are less likely to default. However, as can be seen from Table (2.4.6.2), less corrupt governments pay higher spreads to compensate lenders for the possibility that a more corrupt government will come into power next period and default. Similarly, in the stable economy, the average probability of default is higher when a less corrupt government is in power. However, in a stable economy, the average default episodes are higher when a more corrupt policymaker is in power than when a less corrupt policymaker is in power, but smaller than the unconditional case (see Table (2.4.6.2)).

As we argued above, corruption affects the outcome of our model in many ways.
### Table 2.4.6.2: Default Risk Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>No Turnover</th>
<th>No Turnover</th>
<th>Stable</th>
<th>Unstable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>τ only</td>
<td>τ only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E(Rs)$</td>
<td>0.33%</td>
<td>0.33%</td>
<td>6.69%</td>
<td>0.37%</td>
</tr>
<tr>
<td>$E(Rs</td>
<td>τ_L \text{ is in Power})$</td>
<td>0.33%</td>
<td>-</td>
<td>12.86%</td>
</tr>
<tr>
<td>$E(Rs</td>
<td>τ_H \text{ is in Power})$</td>
<td>-</td>
<td>0.33%</td>
<td>0.43%</td>
</tr>
<tr>
<td>$E(D)$</td>
<td>0.24%</td>
<td>0.23%</td>
<td>5.91%</td>
<td>0.28%</td>
</tr>
<tr>
<td>$E(D</td>
<td>τ_L \text{ is in Power})$</td>
<td>0.24%</td>
<td>-</td>
<td>0.20%</td>
</tr>
<tr>
<td>$E(D</td>
<td>τ_H \text{ is in Power})$</td>
<td>-</td>
<td>0.23%</td>
<td>0.84%</td>
</tr>
<tr>
<td>$Pr(D)$</td>
<td>0.32%</td>
<td>0.33%</td>
<td>5.82%</td>
<td>0.37%</td>
</tr>
<tr>
<td>$Pr(D</td>
<td>τ_L \text{ is in Power})$</td>
<td>0.32%</td>
<td>-</td>
<td>11.13%</td>
</tr>
<tr>
<td>$Pr(D</td>
<td>τ_H \text{ is in Power})$</td>
<td>-</td>
<td>0.33%</td>
<td>0.44%</td>
</tr>
</tbody>
</table>

$E(D)$ is mean number of defaults per annum.

$Pr(D)$ is mean probability of default per annum.

$E(Rs)$ is expected spread per annum.

including the ability to raise the turnover rate, $\pi$, reducing households disposable income and welfare. Political turnover, on the other hand, as observed by Hatchondo et al. (2009) works through two forces to impact on the mean spread. Firstly, an increase in both corruption and turnover results in an increase in the spread paid at intermediate borrowing levels. Secondly, an increase in turnover and corruption makes the intermediate borrowing levels less attractive to policymakers. When turnover is low, policymakers choose intermediate borrowing levels and therefore changes in turnover, $\pi$, are more effective in affecting the spread when turnover, $\pi$, is small to begin with. When turnover, $\pi$, is large to begin with, the second effect of turnover and corruption dominates, as the intermediate region becomes less attractive.

Further more, Table (2.4.6.1) displays the volatility of the model. In the presence of political turnover, the model is able to generate higher spread volatility. When a less corrupt policymaker is in office, the standard deviation of the spread is 0.47% in the economy with high political stability, whereas in the economy with low political stability the standard deviation of spread is 0.32%. In contract, in the economies without political turnover, the standard deviation of spread is 0.18% where only less corrupt governments are in office and 0.17% where only more corrupt governments are in office. Yet, spread is most volatile, (2.02%), in the politically stable economy without
any restriction on the type of government in power. Consumption appears to be most volatile in the politically stable and unstable economies (columns 7 and 8 of Table (2.4.6.1)) without restriction on the type of government in power. Similarly, trade balance is most volatile in the politically stable economy (column 7 of Table (2.4.6.1)) without restriction on the type of government in power. However, the introduction of corruption and political turnover do not significantly affect some business cycle moments including output. Both the level of corruption and political turnover play a major role in generating higher volatility in the model. Additionally, we observe a very strong (positive) correlation between output and consumption in the cases with turnover, when a less corrupt government is in power and for the cases without turnover (when only a less corrupt policymaker or only a more corrupt policymaker is in office). However, the correlation between output and consumption is weaker when there is turnover without restriction on the type in power. Also, we find a counter-cyclical relationship between output and trade balance. Finally, we find a weak and counter-cyclical relationship between spread and both output and trade balance.

2.5 Conclusion

The principal aim of this paper is to explain how the incidence of corruption might impact on sovereign borrowing and default decisions. Our empirical analysis provides strong evidence that higher levels of corruption and political stability are conducive to higher risks of default, and our theoretical analysis shows that corruption can generate significant risks of default and credit spreads when there is enough political stability. We establish that a change in power from a less corrupt to a more corrupt government is more likely to cause default than the reverse. We establish that welfare loss to households increases in the level of corruption. The policy implication of the paper is that corruption and government spending have important roles to play in explaining sovereign default. Efforts by international organisations to prevent sovereign debt crises should not only involve assistance in the design of better fiscal policies, but also tackle the root cause of the problem which is corruption.
2.6 Appendix A

2.6.1 Computational Method

This section describes the computational method we have used to solve the model. We solve the government’s problem by value function iteration using grid search technique over 200 grid points for bond position and 30 grid points for the endowment shock. In the model simulation, we use 1,000 samples of 1,500 periods each. To approximate output we use the Tauchen (1986) approximation process. The computation is done in Fortran 90.

We discretise the asset space into 200 grid points $[b, \bar{b}]$ and endowment space into 30 grid points $[y, \bar{y}]$. We choose a relative error tolerance level, $\varepsilon = 10^{-6}$. We start with an initial guess for the value functions: value of being in power $V^{(0)}$, value of default $V_d^{(0)}$, value of no default $V_{nd}^{(0)}$, and value of being in opposition $\hat{V}^{0}$. We use grid search over the endowment and asset grids to locate the maximum values and update the value functions of being in power: $V^{(1)}$, $V_d^{(1)}$ and $V_{nd}^{(1)}$. Given these updates we then also update the policy functions and bond price. Then using the updated value functions, policy functions and bond price, we update the value of not being in power $\hat{V}^{1}$.

Finally, we compute the distance, $d$, between $V^{(0)}$ and $V^{(1)}$; and $\hat{d}$, between $\hat{V}^{0}$ and $\hat{V}^{1}$. We then evaluate whether the maximum absolute deviation between the new and previous continuation values is below the relative error tolerance level $\varepsilon = 10^{-6}$. If it is, a solution has been found. Otherwise, the optimisation procedure is repeated until the maximum absolute deviation between the new and previous continuation values is below $10^{-6}$.

Using the results from the iteration we simulate the model for 1,000 samples of 1,500 observations each. See Appendix (A.1.2) for details of the code.
2.6.2 Consumption Equivalent Welfare Loss

Let $\lambda$ denote the consumption equivalent of welfare loss, the fraction of consumption one would be willing to give up in each period in the the economy ruled by a non-corrupt policymaker.

$$
E(V_{t}^{\text{non-corrupt}}(\lambda)) = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{((1 + \lambda)c_t)^{1-\varphi} - 1}{1 - \varphi} \right]
$$

$\lambda$ shows up every period and we assume it is deterministic and this reduces to:

$$
E(V_{t}^{\text{non-corrupt}}(\lambda)) = (1 + \lambda)^{1-\varphi} E \left( V_{t}^{\text{non-corrupt}} + \frac{1}{(1 - \varphi)(1 - \beta)} \right) - \frac{1}{(1 - \varphi)(1 - \beta)}
$$

Then we want to find the $\lambda$ that equates this with expected welfare in a corrupt economy (with less corrupt and more corrupt policymakers). We have:

$$
(1 + \lambda)^{1-\varphi} \left( E(V_{t}^{\text{non-corrupt}} + \frac{1}{(1 - \varphi)(1 - \beta)}) \right) - \frac{1}{(1 - \varphi)(1 - \beta)} = E(V_{t}^{\text{corrupt}})
$$

Then

$$
\lambda = \left( \frac{E(V_{t}^{\text{corrupt}}) + \frac{1}{(1 - \varphi)(1 - \beta)}}{E(V_{t}^{\text{non-corrupt}}) + \frac{1}{(1 - \varphi)(1 - \beta)}} \right)^{\frac{1}{1-\varphi}} - 1
$$

If we take the economy with no corrupt policymaker to have higher welfare, then $\lambda < 0$. This means households are willing to give up consumption in the high welfare economy (with no corrupt policymaker) to have the same welfare as an economy with lower welfare (with a corrupt economy).

2.7 Appendix B

2.7.1 List of Tables

2.7.1.1 Data Sample and Description of Terms Used in Regression
Table 2.7.1.1.: Sample of Defaulting and Debt Rescheduling Countries Used for Panel Model

<table>
<thead>
<tr>
<th>Country</th>
<th>Period Examined</th>
<th>Rescheduling+Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>1984-2008</td>
<td>9</td>
</tr>
<tr>
<td>Algeria</td>
<td>1984-2008</td>
<td>1</td>
</tr>
<tr>
<td>Cote D’ivore</td>
<td>1984-2008</td>
<td>8</td>
</tr>
<tr>
<td>Cameroon</td>
<td>1984-2008</td>
<td>9</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>1984-2008</td>
<td>5</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>1984-2008</td>
<td>11</td>
</tr>
<tr>
<td>Ecuador</td>
<td>1984-2008</td>
<td>11</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>1984-2008</td>
<td>6</td>
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<tr>
<td>Gabon</td>
<td>1984-2008</td>
<td>8</td>
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<tr>
<td>Gambia</td>
<td>1984-2008</td>
<td>4</td>
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<tr>
<td>Indonesia</td>
<td>1984-2008</td>
<td>5</td>
</tr>
<tr>
<td>Kenya</td>
<td>1984-2008</td>
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</tr>
<tr>
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<td>2</td>
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<tr>
<td>Moldova</td>
<td>1992-2008</td>
<td>6</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1984-2008</td>
<td>10</td>
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<tr>
<td>Pakistan</td>
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<tr>
<td>Peru</td>
<td>1984-2008</td>
<td>8</td>
</tr>
<tr>
<td>Russia</td>
<td>1992-2008</td>
<td>6</td>
</tr>
<tr>
<td>Sri Lanka</td>
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<tr>
<td>South Africa</td>
<td>1984-2008</td>
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<tr>
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<td>1984-2008</td>
<td>6</td>
</tr>
<tr>
<td>Uruguay</td>
<td>1984-2008</td>
<td>5</td>
</tr>
<tr>
<td>Venezuela</td>
<td>1984-2008</td>
<td>6</td>
</tr>
<tr>
<td>Zambia</td>
<td>1984-2008</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1984-2008</strong></td>
<td><strong>148</strong></td>
</tr>
</tbody>
</table>

The final sample is comprised of 25 countries.
587 observations.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>Sovereign Default/Reschedule</td>
<td>World Bank Development Indicators</td>
<td></td>
</tr>
<tr>
<td>logGDPPC</td>
<td>Logarithm of GDP per Capita</td>
<td>World Bank Development Indicators</td>
<td>(-+)</td>
</tr>
<tr>
<td>corrICRG</td>
<td>ICRG measure of corruption</td>
<td>Political Risk Services</td>
<td>(+)</td>
</tr>
<tr>
<td>Polistability</td>
<td>Political Stability</td>
<td>Freedom House International</td>
<td>(+)</td>
</tr>
<tr>
<td>Extdebt.ratio</td>
<td>External Debt to GDP ratio</td>
<td>World Bank Development Indicators</td>
<td>(+)</td>
</tr>
<tr>
<td>GDPgrowth</td>
<td>Real GDP Growth</td>
<td>World Bank Development Indicators</td>
<td>(-)</td>
</tr>
</tbody>
</table>

ICRG is International Country Risk Guide
GDP per Capita is constant 2000 US dollars
2.7.1.2 *Empirical Model Results*

**Table 2.7.1.3.: Summary Statistics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>0.252</td>
<td>0.435</td>
<td>0</td>
<td>1</td>
<td>587</td>
</tr>
<tr>
<td>corrICRG</td>
<td>3.428</td>
<td>1.039</td>
<td>0</td>
<td>6</td>
<td>584</td>
</tr>
<tr>
<td>Polistability</td>
<td>6</td>
<td>1.891</td>
<td>3</td>
<td>9</td>
<td>575</td>
</tr>
<tr>
<td>logGDPPC</td>
<td>10.737</td>
<td>2.411</td>
<td>6.726</td>
<td>16.03</td>
<td>581</td>
</tr>
<tr>
<td>GDPgrowth</td>
<td>0.035</td>
<td>0.044</td>
<td>-0.171</td>
<td>0.183</td>
<td>582</td>
</tr>
<tr>
<td>Extdebtratio</td>
<td>0.708</td>
<td>0.475</td>
<td>0.032</td>
<td>4.149</td>
<td>573</td>
</tr>
</tbody>
</table>

**Table 2.7.1.4.: Probit models; dependent variable: Default - (excluding lagged default)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>PROB I</th>
<th>PROB II</th>
<th>PROB III</th>
<th>mfx I</th>
<th>mfx II</th>
<th>mfx III</th>
</tr>
</thead>
<tbody>
<tr>
<td>corrICRG_t</td>
<td>0.087</td>
<td>0.113</td>
<td>0.114</td>
<td>0.028</td>
<td>0.036</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>[0.065]</td>
<td>[0.067]*</td>
<td>[0.067]*</td>
<td>[0.021]</td>
<td>[0.021]*</td>
<td>[0.021]*</td>
</tr>
<tr>
<td>Polistability_t</td>
<td>0.082</td>
<td>0.079</td>
<td>0.079</td>
<td>0.026</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>[0.035]**</td>
<td>[0.035]**</td>
<td>[0.035]**</td>
<td>[0.011]**</td>
<td>[0.011]**</td>
<td>[0.011]**</td>
</tr>
<tr>
<td>Extdebtratio_t</td>
<td>0.593</td>
<td>0.602</td>
<td>0.599</td>
<td>0.188</td>
<td>0.190</td>
<td>0.189</td>
</tr>
<tr>
<td></td>
<td>[0.127]***</td>
<td>[0.126]***</td>
<td>[0.128]***</td>
<td>[0.040]***</td>
<td>[0.040]***</td>
<td>[0.040]***</td>
</tr>
<tr>
<td>GDPgrowth_t</td>
<td>-0.099</td>
<td>-0.203</td>
<td>-0.032</td>
<td>-0.064</td>
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<td></td>
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<td>[0.419]</td>
<td></td>
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<td>[0.416]</td>
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<tr>
<td>logGDPPC_t</td>
<td>-0.037</td>
<td>-0.037</td>
<td>-0.012</td>
<td>-0.012</td>
<td></td>
<td></td>
</tr>
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<td>[0.008]</td>
<td></td>
<td></td>
<td>[0.008]</td>
</tr>
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<td>Constant</td>
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<td>-1.577</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>[0.404]***</td>
<td>[0.471]***</td>
<td>[0.473]***</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observations: 557 556 556 557 556 556

Standard errors in brackets
* p<10%, ** p<5%, *** p<1%
Table 2.7.1.5.: Probit models; dependent variable: Default - (excluding lagged default)

<table>
<thead>
<tr>
<th>Variable</th>
<th>PROB I</th>
<th>PROB II</th>
<th>PROB III</th>
<th>mfx I</th>
<th>mfx II</th>
<th>mfx III</th>
</tr>
</thead>
<tbody>
<tr>
<td>corrICRG&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.113</td>
<td>0.128</td>
<td>0.138</td>
<td>0.036</td>
<td>0.040</td>
<td>0.043</td>
</tr>
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<td></td>
<td>[0.066]*</td>
<td>[0.068]*</td>
<td>[0.068]**</td>
<td>[0.021]*</td>
<td>[0.021]*</td>
<td>[0.021]**</td>
</tr>
<tr>
<td>Polistability&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.097</td>
<td>0.094</td>
<td>0.094</td>
<td>0.030</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>[0.035]**</td>
<td>[0.035]**</td>
<td>[0.035]**</td>
<td>[0.011]**</td>
<td>[0.011]**</td>
<td>[0.011]**</td>
</tr>
<tr>
<td>Extdebtratio&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.583</td>
<td>0.616</td>
<td>0.587</td>
<td>0.183</td>
<td>0.193</td>
<td>0.183</td>
</tr>
<tr>
<td></td>
<td>[0.125]**</td>
<td>[0.124]**</td>
<td>[0.125]**</td>
<td>[0.039]**</td>
<td>[0.039]**</td>
<td>[0.039]**</td>
</tr>
<tr>
<td>GDPgrowth&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>-1.908</td>
<td>-2.006</td>
<td>-0.599</td>
<td>-0.627</td>
<td>-0.627</td>
<td>-0.627</td>
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<tr>
<td></td>
<td>[1.305]</td>
<td>[1.302]</td>
<td>[0.410]</td>
<td></td>
<td></td>
<td>[0.407]</td>
</tr>
<tr>
<td>logGDPPC&lt;sub&gt;t−1&lt;/sub&gt;</td>
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<td>-0.032</td>
<td>-0.032</td>
<td>-0.010</td>
<td>-0.010</td>
<td>-0.010</td>
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<tr>
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<td>[0.008]</td>
<td></td>
<td></td>
<td>[0.008]</td>
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<td>-1.746</td>
<td>-2.018</td>
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<tr>
<td></td>
<td>[0.410]**</td>
<td>[0.479]**</td>
<td>[0.481]**</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Observations 556 555 555 556 555 555

Standard errors in brackets
* p<10%, ** p<5%, *** p<1%

Table 2.7.1.6.: Probit models; dependent variable: Default - (including lagged default)

<table>
<thead>
<tr>
<th>Variable</th>
<th>PROB I</th>
<th>PROB II</th>
<th>PROB III</th>
<th>mfx I</th>
<th>mfx II</th>
<th>mfx III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.666</td>
<td>0.646</td>
<td>0.649</td>
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<td>0.217</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>[0.131]**</td>
<td>[0.131]**</td>
<td>[0.131]**</td>
<td>[0.046]**</td>
<td>[0.047]**</td>
<td>[0.047]**</td>
</tr>
<tr>
<td>corrICRG&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.102</td>
<td>0.112</td>
<td>0.123</td>
<td>0.031</td>
<td>0.034</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>[0.067]</td>
<td>[0.069]</td>
<td>[0.070]*</td>
<td>[0.021]</td>
<td>[0.021]</td>
<td>[0.021]*</td>
</tr>
<tr>
<td>Polistability&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.083</td>
<td>0.081</td>
<td>0.081</td>
<td>0.026</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>[0.036]**</td>
<td>[0.036]**</td>
<td>[0.036]**</td>
<td>[0.011]**</td>
<td>[0.011]**</td>
<td>[0.011]**</td>
</tr>
<tr>
<td>Extdebtratio&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>0.462</td>
<td>0.500</td>
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<td>0.142</td>
<td>0.154</td>
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</tr>
<tr>
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<td>[0.128]**</td>
<td>[0.126]**</td>
<td>[0.128]**</td>
<td>[0.039]**</td>
<td>[0.039]**</td>
<td>[0.039]**</td>
</tr>
<tr>
<td>GDPgrowth&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>-2.027</td>
<td>-2.110</td>
<td>-0.625</td>
<td>-0.648</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[1.326]</td>
<td>[1.323]</td>
<td>[0.409]</td>
<td></td>
<td></td>
<td>[0.406]</td>
</tr>
<tr>
<td>logGDPPC&lt;sub&gt;t−1&lt;/sub&gt;</td>
<td>-0.025</td>
<td>-0.027</td>
<td>-0.027</td>
<td>-0.008</td>
<td>-0.008</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>[0.026]</td>
<td>[0.026]</td>
<td>[0.008]</td>
<td></td>
<td></td>
<td>[0.008]</td>
</tr>
<tr>
<td>Constant</td>
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<td>-1.853</td>
<td>-1.774</td>
<td>-2.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.417]**</td>
<td>[0.489]**</td>
<td>[0.490]**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observations 556 555 555 556 555 555

Standard errors in brackets
* p<10%, ** p<5%, *** p<1%
2.7.1.3 Theoretical Model Results

Table 2.7.1.7.: Mean Number of Defaults Given Change in Type

<table>
<thead>
<tr>
<th></th>
<th>Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stable</td>
</tr>
<tr>
<td>Expected Number of Defaults Given Change to Less Corrupt</td>
<td>0.00%</td>
</tr>
<tr>
<td>Expected Number of Defaults Given Change to More Corrupt</td>
<td>95.5%</td>
</tr>
</tbody>
</table>

Mean number of defaults per annum.
Chapter 3

Limited Contract Enforcement and Firm Financing

3.1 Introduction

The role that financial factors and financial development play in economic activity has long been documented in the business cycle literature (see Gertler (1988); Carlstrom and Fuerst (1997, 1998)). However, this role (such as smoothing fluctuations and enhancing productive efficiency) hinges crucially on the existence of good institutions where financial contracts are well enforced. Hence, when the market for loans has an imperfection such that agents can choose to default on their debt at an exogenous cost governed by the quality of institutions, economic development becomes undermined. Levine et al. (2000) find that contract enforcement promotes financial development, while the latter is conducive to economic growth. In particular, developing economies do not only have weak legal institutions to enforce contracts but are also characterised by high lending rates, unavailability of capital and a generally risky investment environment.

There is a broad literature on asymmetric information and agency costs associated with financial markets (see Bernanke et al. (1999); De Fiore et al. (2011); Carlstrom and Fuerst (1998, 2001); Carlstrom et al. (2010)). Recent models of agency costs normally assume that borrowers possess private information which lenders can gain access to
only after paying some monitoring or verification cost. This paper seeks to contribute
to the literature on agency costs, asymmetric information and financial development
by studying the role of limited contract enforcement\textsuperscript{1} in a Dynamic Stochastic General
Equilibrium (DSGE) framework. We do so by allowing for the possibility of the firm
being able to default on bank loans when it is still solvent. At the same time, a
defaulting firm faces the prospect of being punished if it is caught. This punishment
involves the confiscation of some fraction of a firm’s capital output, where the size of
this fraction depends on the quality of legal institutions. Given limited enforcement,
an entrepreneur may decide to default even though its solvent. The results of the paper
emphasise the role that limited enforcement plays in determining the default risk and
access to funding by small firms.

The growth of firms depends on the level of access to external financing which
in turn depends largely on the informational asymmetries and the contractual ar-
rangements between investors and entrepreneurs. In a dynamic general equilibrium
framework, Amaral and Quintin (2010) find that the average scale of production in-
creases with the quality of enforcement and that the importance of limited enforcement
rises with the importance of capital in production\textsuperscript{2}. Whilst imperfect information cre-
ates uncertainty about the default risk of borrowers, limited enforceability of financial
contracts reflects how much lenders loose in the event that borrowers default.

The above analysis yields interesting insights although one issue that is not looked
at is the effect of limited enforcement on firm funding and default risk. Costly contract
enforcement means that lenders will receive less compensation when firms default which
will impact on default risk. In turn, this will alter contract arrangements and vice versa.
Imperfect information can have important implications for borrowing and lending,
especially when there is limited enforcement of contracts.

Limited enforceability of contracts is especially important for new and smaller
firms who face working capital constraints and collateral problems which mean that

\textsuperscript{1}Limited contract enforcement refers to the difficulty with which lenders can recover defaulted loans.
Also, the World Bank have likened (limited) contract enforcement to the time and cost for resolving
commercial dispute through courts.

\textsuperscript{2}That is to say bad enforcement results in self-financing of production and on a small scale.
they rely mostly on external (as opposed to internal) financing. This has implications not only for the growth of small firms but also for aggregate growth and welfare. It is argued by Albuquerque and Hopenhayn (2000) that strong enforceability can help explain the growth of small and new firms. Amaral and Quintin (2010) find that weak enforceability has a negative effect on small firms’ access to finance, arguing that such firms are forced to rely mainly on self-funding and to operate on a small scale because of credit constraints which deny them of external funding. Additionally, Steinberg (2013) argued that in countries with imperfect financial markets, productive firms are mostly financially constrained. As a result, firms are impaired from borrowing enough to reach their optimal sizes.

In spite of the above, little research has been conducted–especially within the context of a DSGE framework–on exploring the interlinkages between limited contract enforcement, asymmetric information, financial intermediation and firm funding. The present paper seeks to do this. In particular, we study the implications of limited enforcement for financial intermediation, small firm funding, economic growth and welfare in a DSGE framework. We do this by modifying the models of Carlstrom and Fuerst (1997) to allow for the imperfect enforcement on loan contracts. In doing so, we draw upon the works of Khan and Ravikumar (2001), Marcet and Marimon (1992), Castro et al. (2004), Quintin (2000), Cooley et al. (2003), Boedo et al. (2011), Bernanke et al. (1999), De Fiore et al. (2011), and Amaral and Quintin (2010). Our work relates with Cooley et al. (2003) on the assumption that firms which default in one period are not excluded from the financial market in subsequent periods. We make the same assumption, but also assume that firms can use funds from defaulting in next period production. Marcet and Marimon (1992) argue that better investor protection in the form of better contract enforcement leads to better risk sharing which creates a greater supply of loanable funds. This results in a greater demand for capital which leads to a higher interest rate but which also raises the income of households; at the same time, there is a reduction in entrepreneurs’ income, a reduction in current savings and
a reduction in next period capital\textsuperscript{3}. Their central conclusion is that better contract enforcement results in less growth. We challenge this conclusion by arguing that better contract enforcement helps in the transfer of resources to lenders (households) which is accessed via banks by small firms to finance investment projects.

We show that business cycle fluctuations and the volatility of output are affected by the degree of limited contract enforcement. Specifically, we establish that limited enforcement amplifies the effects of shocks on the economy. We also find that limited enforcement coupled with the ability of firms to default when solvent creates a problem for the establishment and growth of smaller firms as a result of over accumulation of internal funds by larger firms. Finally, given that firms are able to default when solvent, and that households provide loanable funds, we also demonstrate that limited enforcement is associated with welfare loss to households.

As indicated earlier, our work follows Bernanke et al. (1999), De Fiore et al. (2011), Carlstrom and Fuerst (1998, 2001), and Carlstrom et al. (2010) on asymmetric information in financial markets. To engage in investment opportunities, risk neutral entrepreneurs have the potential to access funds from lenders. However, this funding is constrained because of the agency costs involved. Lenders are risk averse households who offer loans to entrepreneurs through the Capital Market Fund (CMF)/Bank. A key feature of our model is the distinction between the monitoring cost and enforcement cost, in the event that an entrepreneur defaults on its loan. We show how a high degree of limited enforcement results in a loss of welfare to households and the economy in general. We find that a high degree of limited contract enforcement reduces the supply of funds and impedes small firms’ access to working capital which has implications for the growth of the economy. We establish that the probability of default, risk premium and the resulting cost of borrowing increase monotonically with the degree of limited contract enforcement. We also show that the effects of both aggregate productivity and wealth transfer shocks are amplified by an increase in the degree of limited contract enforcement.

\textsuperscript{3}A supply side effect works through the demand effect. When the supply side effect is stronger, the stricter the restrictions on capital flows (Castro et al. (2004)).
As a motivation for our theoretical analysis, we first conduct an empirical investigation into the effect of limited enforcement and poor depth of credit information on output. Depth of credit information in our empirical work relates closely to the monitoring cost in our theoretical model. In a similar vein, limited enforcement in our empirical work proxies for the degree of limited enforcement in our theoretical model, which pertains to the “cost” that lenders have to incur (through the legal system e.g. legal fees) in order to recover any “hidden capital from defaulting firms. Using data on a broad sample of countries, we find that limited enforcement affects output negatively. Also, we find that poor credit information has negative impact on output. This results are robust to various sensitivity tests.

The rest of the paper is organised as follows. In Section (3.2), we present the empirical analysis of the effect of limited enforcement on output. In Section (3.3), we set out the theoretical model that we use to study the relationship between firm funding and limited enforcement of contracts and provide the solution. We then calibrate the model and present our findings. In Section (3.4), we make some concluding remarks.

### 3.2 Empirical Observations

As a prelude to our theoretical analysis, we first conduct an empirical investigation into the relationship between financial contract enforcement and aggregate economic activity. Specifically, we seek to obtain evidence about the extent to which limited enforcement\(^4\) has influence on both the level and volatility of output either directly or indirectly. The literature on contract enforcement have stressed it importance in economic growth (see Monge-Naranjo (2009); Steinberg (2013)). Using data on credit information and enforcement costs, Steinberg (2013) finds that the latter exacerbates the effects of poor depth of credit information on total factor productivity. Additionally, their finding is consistent with other studies on the effect of credit bureaus and borrowers’ information on access to credit, in countries with limited contract enforce-

\(^4\) We use a measure of limited enforcement different than the one used by Cooley et al. (2003).
ment (see Djankov et al. (2007); Jappelli and Pagano (2002); Brown et al. (2009)). Further to this, Monge-Naranjo (2009) finds countries where the legal system gives priority to creditors to have better-developed banks and improved private sector credit as a ratio of GDP, than countries where laws do not give a high priority to creditors.

3.2.1 Data and Methodology

We use data from the World Bank’s Development Indicators and the World Bank’s Doing Business Index from 2004 to 2012 for a sample of 57 countries (including both developed and developing countries). A list of these countries is given in Appendix (3.6). Our measure of output is logarithm of real GDP, whilst we proxy for imperfect contract enforcement using the contract enforcement cost index. Djankov et al. (2002) developed the methodology used by the World Bank for constructing the contract enforcement cost index. Typically, the index captures the cost, as a fraction of the claim (total amount of loans defaulted upon), that a lender (complainant) may incur in order to enforce a contract. Accordingly, therefore, a higher value of this index means that contracts will be more costly to enforce. A higher value of the contract enforcement measure means that enforcement is more costly. For present purposes, we convert this to the fraction of defaulted debt recovered by lenders after default is announced. An increase in the value of this is then understood to mean an improvement in contract enforcement.

As an additional measure of financial market imperfections, we also include the depth of credit information (improvements in which are indicated on a scale from 0 to 6). The methodology used by the World Bank to construct the depth of credit index was developed by Djankov et al. (2007). This index measures the coverage, scope and accessibility of information about the credit histories of individuals and firms. Depth of credit information could be related to monitoring and verification cost in our theoretical model. Accordingly, bad depth of credit information implies high monitoring and verification cost and low output, in the theoretical model (see Table (3.3.3.5)). Table (3.6.1.3) reports the summary statistics of these variables. Depth
of credit information is the most volatile variable followed by output and contract enforcement. This implies volatility of 2.048, 1.031 and 0.395, respectively.

Figure (3.2.1.1) presents the scatter plots of output, contract enforcement and depth of credit information. Figure (3.2.1.1) shows that output is positively correlated with both contract enforcement and credit information.

Figure 3.2.1.1.: Scatter Plot of Real GDP, Credit Information and Contract Enforcement

Figure (3.2.1.2) presents the scatter plots of output volatility and contract enforcement. Figure (3.2.1.2) shows that the volatility of output is negatively correlated with contract enforcement.
Figure 3.2.1.2.: Scatter: Standard Deviation of GDP and Contract Enforcement

The foregoing casual inspection of the data is supplemented with an econometric investigation in which we estimate the following equation adopted from Steinberg (2013):

$$ \log \text{RealGDP}_{it} = \begin{cases} \gamma + \alpha_1 \text{CONENF}_{it} + \alpha_2 \text{CREINFO}_{it} + \\
\alpha_3 \text{CONENF} \times \text{CREINFO}_{it} + \eta_i + \mu_t + \varepsilon_{it} \end{cases} $$

where $i$ is the country index and $t$ is time. The dependent variable is the logarithm of real GDP. The variable $\text{CONENF}_{it}$ measures the amount of debt recovered through contract enforcement after default by firms. In other words it shows how much investors are able to recoup, through the legal system, from firms that declare bankruptcy. The
variable $CREINFO_{it}$ denotes the depth of credit information. The credit information of a country is ascertained from data on firms, individuals, utility companies and financial institutions in the form of their credit history which is available to all parties. $CONENF \times CREINFO_{it}$, is the interaction between contract enforcement and credit information. The intuition behind this interaction term is to capture the effect of contract enforcement on output given credit information or the effect of credit information on output given the degree of contract enforcement. By doing this we are able to mimic the outcome of the interaction between the monitoring/verification cost parameter (which proxies depth of credit information) and the limited enforcement parameter in our theoretical model. The country and time fixed effects are $\eta_i$ and $\mu_t$ respectively while $\varepsilon_{it}$ is the error term. The model is estimated in Stata and the code is provided in Appendix (A.2).

3.2.2 Results

The results of the estimation are presented in this section. We use both fixed effects (FE) and random effects (RE). There are no significant differences between the FE and RE estimates. Given this, we prefer the random effect specification because it is more efficient. The results in Table (3.6.1.4) are for both time and country FE and RE. The coefficient on contract enforcement has the expected (positive) sign and is significant at 1% in all specifications (columns). The coefficients from the RE models are, however, larger than the FE models. Similarly, the depth of credit information has the expected (positive) sign and significant at 1% as well. The coefficient on the interaction term is negative and significant at 5%.

Table (3.6.1.5) displays the results for country FE and RE. Consistent with the results in Table (3.6.1.4), we find that the coefficients on contract enforcement and depth of credit information have positive sign and significant at 1% in all specifications. Again, we find that the coefficients from the RE models are, however, larger than the FE models. Additionally, we observe that, generally, the country effects models have larger coefficients than the time and country effects models. Finally, the coefficient
on the interaction term is negative and significant at 1% in the country FE and RE models.

The results in Table (3.6.1.6) are for both time and country FE and RE for sub-sample of 34 countries. Table (3.6.1.6) (see in appendix (3.6)) report the results for a sub-sample of 34 countries which display most variation in their time series data. Consistent with the results in Table (3.6.1.4), we find that the coefficients on contract enforcement have positive sign and significant at 1% in all specifications. Depth of credit information has positive and significant coefficients in all specifications except in column 8 in Table (3.6.1.6). We find that the coefficients from the RE models are, however, larger than the FE models. Surprisingly too, the coefficient on the interaction term is negative and insignificant.

Table (3.6.1.7) displays the results for country FE and RE for sub-sample of 34 countries. We find that the coefficients on contract enforcement and depth of credit information have positive sign and significant at 1% in all specifications. We find that the coefficients from the RE models are, however, larger than the FE models. Also, we observe that, generally, the country effects models have larger coefficients than the time and country effects models. Contrary to the results in Table (3.6.1.6), the coefficient on the interaction term is negative and significant at 1% in the country FE and RE models in Table (3.6.1.7).

The positive and significant coefficient on contract enforcement indicates that output increases when the cost of contract enforcement is low meaning that investors are able to recoup a larger amount of debt when firms default. Similarly, the positive and significant coefficient on the depth of credit information implies that when credit information on borrowers is more available, investors are more capable of identifying firms with good prospects and allocating loans towards these firms. In sum, the coefficients on contract enforcement and the depth of credit information indicate that both measures of financial development are positively related to output. The negative and significant coefficient on the interaction term means that, given an economy with weak contract enforcement, a deterioration of the existing level of credit information is likely
to dampen the fall in output (or alternatively, given low depth of credit information, a deterioration in contract enforcement is likely to dampen the fall in output). In other words, the effect of contract enforcement on output is smaller when the depth of credit information is higher (or alternatively, when contract enforcement is higher the effect of depth of credit information on output is smaller) and vice versa. Either way, the result suggests that different types of financial market imperfection tend to show negative synergy between them—they are inhibiting each other.

Our result also indicates that the effect of contract enforcement on output depends on credit information, which is consistent with the prediction of our theoretical model (see Table (3.3.3.5)). Table (3.3.3.5) also shows that output increases with better credit information (lower monitoring cost) and better contract enforcement (lower cost of enforcement).

3.3 The Investment Model

The model is based on Carlstrom and Fuerst (1997), extended to allow for imperfect contract enforcement. The model economy consists of a continuum of agents of unit mass, a fraction \((1 - \eta)\) of which are risk averse households and a fraction \(\eta\) are risk neutral entrepreneurs (or capital producing firms). Households who own (shares in) the consumption-good producing firms also supply labour and rent capital to these firms, invest in capital and advance intra-period loans via Capital Market Fund (CMF)/Bank to entrepreneurs. Entrepreneurs produce capital goods using net worth and external funds in the form of loans from the CMF/Bank.

3.3.1 The Financial Contract

In this section we discuss the financial contract in a partial equilibrium setting. It is one period in length, negotiated at the beginning of the period and resolved by the end of the same period. The contract involves the entrepreneur and the lender both of
which are risk neutral\textsuperscript{5}. The lender has resources that he can lend to entrepreneur with some positive net worth. Each entrepreneur is endowed with a stochastic technology that transforms $i$ consumption goods into $\omega_i$ units of capital, where $\omega$ is idiosyncratic technology shock. The shock $\omega$, is \textit{i.i.d.} across time and across entrepreneurs, with cumulative distribution function $\Phi$ and probability density function $\phi$. We assume $\omega$ has mean $\mathbb{E}[\omega] = 1$, standard deviation $\sigma_\omega$, and is privately observed by the entrepreneur, but others can privately observe $\omega$ only after paying the monitoring cost of $\mu i$ capital units. The monitoring cost denominated in terms of capital is proportional to $i$ and independent of the realisation of $\omega$. To ensure that the asymmetric information in the model is important, we assume that net worth is sufficiently small so that entrepreneurs would like to receive some external financing to finance investment. Otherwise, entrepreneurs would not need to borrow to finance investment. To finance the investment $i$, the entrepreneur uses its net worth $n$ and borrows $(i - n)$ consumption goods and agrees to repay $(1 + r^k)(i - n)$ capital goods to the lender, where $r^k$ is the lending rate. Entrepreneur defaults at the end of the period if the realisation of $\omega$ is low. However, if the entrepreneur defaults, it can “hide” a fraction $\zeta$ of the capital. The inability of lenders to recover this “hidden” capital due to weakness in legal institutions is what we refer to as limited contract enforcement. While monitoring cost ($\mu i$ capital units) pertains to the cost of monitoring borrowers, limited enforcement involves the “cost” that lenders have to incur (which is equivalent to volume of this “hidden” capital) in order to recover the “hidden capital. Therefore, if the entrepreneur does not default, it receives:

$$\omega i - (1 + r^k)(i - n)$$ \hfill (3.3.1.1)

\textsuperscript{5} In the general equilibrium setting, risk-averse households are the source of loanable funds to entrepreneurs. However, in terms of the financial contract, they will be effectively risk neutral because (1) there will be no aggregate uncertainty over the duration of the contract and (2) households can diversify away all idiosyncratic risk.
capital goods, which it can then sell at the price $q$ (the price of aggregate capital). If the entrepreneur defaults, however, it receives:

$$\zeta \omega i$$

Comparing Equations (3.3.1.1) and (3.3.1.2), the entrepreneur will default if and only if

$$(1 - \zeta) \omega i < (1 + r^k)(i - n)$$

This is equivalent to Carlstrom and Fuerst (1997) when $\zeta = 0$.

It is then possible to define a default threshold $\bar{\omega}$ such that the entrepreneur will default for $\omega < \bar{\omega}$ and not default for $\omega \geq \bar{\omega}$. This threshold is determined by:

$$(1 - \zeta) \bar{\omega} i = (1 + r^k)(i - n) \tag{3.3.1.3}$$

If $\omega \geq \bar{\omega}$, the entrepreneur does not default and he receives $\omega i - (1 + r^k)(i - n)$. If $\omega < \bar{\omega}$, the entrepreneur defaults and he receives $\zeta \omega i$. In both cases, the entrepreneur can then sell the capital it has at the price $q$. Therefore, expected entrepreneurial income is given by

$$q \left[ \int_{0}^{\bar{\omega}} \zeta \omega d\Phi(\omega) + \int_{\bar{\omega}}^{\infty} [\omega i - (1 + r^k)(i - n)] d\Phi(\omega) \right]$$

Using Equation (3.3.1.3) to substitute for $(1 + r^k)(i - n)$, this becomes:

$$qi \left[ \zeta \int_{0}^{\bar{\omega}} \omega d\Phi(\omega) + \int_{\bar{\omega}}^{\infty} \omega d\Phi(\omega) - (1 - \zeta) \bar{\omega} (1 - \Phi(\bar{\omega})) \right]$$

Therefore, as a result of this contract, the entrepreneur expects to receive $qif(\bar{\omega})$, where $f(\bar{\omega})$ is the the fraction of the expected capital output received by the entrepreneur. This is defined to be:
\[
f(\bar{\omega}) = 1 - (1 - \zeta) \left[ \int_0^{\bar{\omega}} \omega \Phi(\omega) + \bar{\omega}(1 - \Phi(\bar{\omega})) \right]
\] (3.3.1.4)

Similarly, for the lender, if \( \omega \geq \bar{\omega} \), the entrepreneur does not default and the lender receives \((1 + r^h)(i - n)\) in capital units. If \( \omega < \bar{\omega} \), the entrepreneur defaults and the lender receives \(((1 - \zeta)\omega - \mu)i\) capital units. Then expected lender’s income is given by

\[
q \left[ \int_0^{\bar{\omega}} ((1 - \zeta)\omega - \mu)i \Phi(\omega) + \int_{\bar{\omega}}^{\infty} (1 + r^h)(i - n) d\Phi(\omega) \right]
\]

Again, using Equation (3.3.1.3), the expected lender’s income simplifies to

\[
qi \left[ (1 - \zeta) \left\{ \int_0^{\bar{\omega}} \omega \Phi(\omega) + \bar{\omega}(1 - \Phi(\bar{\omega})) \right\} - \mu \Phi(\bar{\omega}) \right]
\]

As a result of this contract, the lender expects to receive \( qig(\bar{\omega}) \), where \( g(\bar{\omega}) \) is the fraction of the expected capital output received by the lender. This is defined to be:

\[
g(\bar{\omega}) = (1 - \zeta) \left[ \int_0^{\bar{\omega}} \omega \Phi(\bar{\omega}) + \bar{\omega}(1 - \Phi(\bar{\omega})) \right] - \mu \Phi(\bar{\omega})
\] (3.3.1.5)

Moreover, using Equations (3.3.1.4) and (3.3.1.5) we arrive at

\[
f(\bar{\omega}) + g(\bar{\omega}) = 1 - \mu \Phi(\bar{\omega})
\] (3.3.1.6)

This implies that, on average, monitoring results in the destruction of some of the produced capital, and the remainder of this capital is then split between the entrepreneur and the lender.

The optimal contract is given by the pair \((i, \bar{\omega})\) (taking as given net worth \(n\) and capital price \(q\)) which solves:

\[
\max_{i, \bar{\omega}} qif(\bar{\omega})
\]
subject to

\[ q_{ig}(\bar{\omega}) \geq i - n \] Lender’s Participation constraint

\[ q_{if}(\bar{\omega}) \geq n \] Entrepreneur’s Participation constraint, which is always satisfied

The solution\(^6\) to the optimal contract is the following:

\[
q \left[ 1 - \mu \Phi(\bar{\omega}) - \frac{\mu \phi(\bar{\omega}) f(\bar{\omega})}{(1 - \zeta)(1 - \Phi(\bar{\omega}))} \right] = 1 \tag{3.3.1.7}
\]

This can also be written as:

\[
q \left[ 1 - \mu \Phi(\bar{\omega}) + \mu \phi(\bar{\omega}) \frac{f(\bar{\omega})}{f'(\bar{\omega})} \right] = 1
\]

This implicitly defines a function \( \bar{\omega}(q) \). Then, given \( \bar{\omega}(q) \), we can solve for optimal investment using the participation constraint of the lender:

\[
i(q, n) = \frac{n}{1 - qg(\bar{\omega}(q))} \tag{3.3.1.8}
\]

Substituting in \( \bar{\omega}(q) \), this gives us the function \( i(q, n) \), which represents the optimal amount of consumption goods placed into the capital-producing technology (given \( q \) and net worth \( n \)). Expected capital output is then given by:

\[
I^*(q, n) \equiv i(q, n) [1 - \mu \Phi(\bar{\omega}(q))]
\]

This can be interpreted as the investment supply function. This implies that the supply function of entrepreneurs aggregates. Aggregate investment depends only on the economy-wide price of capital \( q \) and aggregate net worth. It can then be shown that \( \partial I^*/\partial q > 0 \) and \( \partial I^*/\partial n > 0 \).

An entrepreneur who receives loan of one unit of consumption good from household (via CMF/bank) expects to make a risky return of \( q(1 + r^k) \) consumption good

\(^6\)See Appendix (3.5.4) for detailed derivation.
at the end of the investment period. Therefore, the risk premium of the model is 
$q(1 + r^k) - 1$. Substituting for $(1 + r^k)$ using Equation (3.3.1.3), the risk premium can 
also be written as:

\[ q(1 + r^k) - 1 = q(1 - \zeta)\bar{\omega} \frac{i}{i - n} - 1 \]

Finally, we may define leverage $z$, of the entrepreneur as the ratio of external 
funding $(i - n)$ to net worth $n$ of the entrepreneur. This is given by

\[ z = \frac{i - n}{n} \]

Then using Equation (3.3.1.8) this can be re-written as:

\[ z = \frac{qg(\bar{\omega}(q))}{1 - qg(\bar{\omega}(q))} \]

3.3.2 The General Equilibrium Model

We now embed the contracting problem into a standard RBC model. We further 
assume that, using consumption goods, new capital is created at the end of the period 
with a non-stochastic one-to-one transformation rate. The newly produced capital is 
then utilised in the next period. We use the same timing in this model. The one-
to-one transformation assumption is replaced with the contracting problem so that a 
household who wants to purchase capital, must first fund the production of capital (an 
entrepreneurial project), which is subject to agency problems.

The economy consists of a continuum of agents of unit mass, a fraction $(1 - \eta)$ 
of which are households and a fraction $\eta$ are entrepreneurs. Firms produce the single 
consumption good, but it is assumed that these consumption-producing firms are not 
subject to any agency problems.
3.3.2.1 Households

Households are infinitely lived, with preferences:

$$
\mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - L_t) \right]
$$

where $U(c_t, 1 - L_t) = \ln(c_t) + \nu(1 - L_t)$ is the instantaneous utility function, $\mathbb{E}$ is the expectation operator conditional on period 0 information, $\beta \in (0, 1)$ is the discount factor, $c_t$ is household consumption, $L_t$ is labour. Households supply labour to consumption-producing firms at wage rate $w_t$, rent their accumulated capital holdings to consumption-producing firms at rental rate $r_t$, purchase consumption from these firms at the price 1 (note that consumption is the numeraire), and purchase new capital goods at a price of $q_t$. Within the period, households also lend to entrepreneurs (through the CMF/Bank) to help finance the production of capital. Households who own (shares in) the consumption-good producing firms then purchase capital goods at the end of the period with the assistance of CMF/Bank.

The budget constraint faced by the household is then:

$$
c_t + q_t \left[ k_{t+1}^h - (1 - \delta)k_t^h \right] = w_t L_t + r_t k_t^h
$$

where $k_t^h$ is the stock of capital owned by the representative household. The profits of the CMF/bank are not included here, because they will be zero.

Optimal consumption-labour decision is determined by the following:

$$
w_t = \frac{U_L(c_t, 1 - L_t)}{U_c(c_t, 1 - L_t)}
$$

Also, optimal\(^7\) household consumption-investment decision is determined by the following:

$$
q_t U_c(c_t, 1 - L_t) = \beta \mathbb{E}_t \left\{ U_c(c_{t+1}, 1 - L_{t+1}) [q_{t+1} (1 - \delta) + r_{t+1}] \right\}
$$

\(^7\)See Appendix (3.5.1) for detailed derivation.
3.3.2.2 Consumption-good Producing Firms

There are a continuum of consumption-producing firms in the economy who utilise a standard production function with Constant Returns to Scale (CRS) specified as:

\[ Y_t = A_t F(K_t, H_t, H_e^t) \]

where \( Y_t \) is aggregate output of the consumption good, \( K_t \) is the aggregate capital stock (including entrepreneurial capital), \( H_t \) is aggregate supply of household labour, and \( H_e^t \) is the aggregate supply of entrepreneurial labour. \( A_t \) is stochastic aggregate productivity and evolves according to \( \log(A_t) = (1 - \rho_A)A + \rho_A \log(A_{t-1}) + \varepsilon_t \), where \( \varepsilon_t \) is a serially uncorrelated, i.i.d. and normally distributed shock; and \( \rho_A \) is the autocorrelation coefficient. This consumption-good producing technology is assumed to be Cobb-Douglas (details to be discussed in Section (3.3.3)). Perfect competition in factor markets ensures that factor prices are equal to their respective marginal products:

\[ r_t = A_t F_1(K_t, H_t, H_e^t), \quad w_t = A_t F_2(K_t, H_t, H_e^t), \quad w_e^t = A_t F_3(K_t, H_t, H_e^t), \]

where \( w_e^t \) is the wage rate for entrepreneurial labour. As explained in Carlstrom and Fuerst (1997), the assumption of entrepreneurial labour income is to ensure that each entrepreneur has a non-zero level of net worth. This is because the financial contracting problem will not be well defined for any zero levels of net worth.

3.3.2.3 Entrepreneurs

Entrepreneurs are long-lived and risk-neutral. Without any restrictions, entrepreneurs will want to accumulate enough capital so that they are completely self-financed and avoid agency costs by postponing consumption. To prevent this, we follow on Carlstrom and Fuerst (1997) and assume that entrepreneurs discount the future more heavily than households. Following the risk neutrality assumption, entrepreneurs maximise

---

8 We specify the production function as \( Y_t = A_t K_1^{\alpha_K} H_t^{\alpha_H} H_e^{\alpha_e} \).

9 In the earlier working paper version of their paper, Carlstrom and Fuerst (1997) assumed that a constant fraction of the entrepreneurs died each period, and sold their accumulated capital stock to households. In terms of consumption, this is equivalent to assuming that the entrepreneurs consume a constant fraction of their capital holdings each period.
the following objective function:

$$E_0 \left[ \sum_{t=0}^{\infty} (\beta \gamma)^t c_t^e \right]$$  \hspace{1cm} (3.3.2.1)

where $c^e_t$ is entrepreneurial consumption, and $\gamma \in (0, 1)$ denotes the additional rate of discounting for entrepreneurs to ensure that $\beta \gamma < \beta$. At the beginning of the period the entrepreneur rents his previously accumulated capital and also inelastically supplies labour, which we assume to be unity, to consumption good producing firms. The entrepreneur then sells his remaining un-depreciated capital to households for consumption goods. The net worth of the entrepreneur (in terms of consumption) at the end of the transactions period is given by:

$$n_t = w^e_t + k^e_t \left[ q_t (1 - \delta) + r_t \right]$$

where $k^e_t$ refers to the capital holdings of the individual entrepreneur at the beginning of the period. To undertake investment, the entrepreneur uses this net worth to form the basis for any loan agreement that he will enter into with the lender. Risk neutrality and the high internal return ensures the entrepreneur pours his entire net worth into the capital-producing technology and borrows from the household (via the CMF/Bank). Given the financial contract from Section (3.3.1), the entrepreneur chooses $i_t = i(q_t, n_t)$, where $i(q, n)$ is defined in Equation (3.3.1.8). There is also an associated cutoff $\bar{\omega}_t = \bar{\omega}(q_t)$, where $\bar{\omega}(q)$ is implicitly defined by Equation (3.3.1.7), given this investment. Let $x_t$ denote the realised payoff (in terms of capital) to the entrepreneur given by:

$$x = \begin{cases} 
\omega i - (1 + r^k)(i - n) = \omega i - (1 - \zeta)\bar{\omega}i = (\omega - (1 - \zeta)\bar{\omega})i & \text{if } \omega \geq \bar{\omega} \\
\zeta \omega i & \text{if } \omega < \bar{\omega} \end{cases}$$

Then, given $x$, the entrepreneur makes the consumption decision:

$$c^e_t + q_t k^e_{t+1} = q_t x_t$$
Let $\bar{c}_t^e$ denote average entrepreneurial consumption. Then $\eta \bar{c}_t^e$ is aggregate entrepreneurial consumption. Aggregating across the budget constraints of all entrepreneurs, we get:

$$\eta \bar{c}_t^e + q_t K_{t+1}^e = q_t \frac{N_t}{1 - q_t g(\bar{\omega}(q_t))} f(\bar{\omega}(q_t))$$

where $K_{t+1}^e$ is aggregate entrepreneurial capital stock and $N_t$ is aggregate entrepreneurial net worth. Aggregate net worth is $N_t = \eta w_t^e + K_t^e(q_t(1 - \delta) + r_t)$. Re-arranging, tomorrow’s aggregate entrepreneurial capital stock ($K_{t+1}^e$) is given by:

$$K_{t+1}^e = [\eta w_t^e + K_t^e(q_t(1 - \delta) + r_t)] \frac{f(\bar{\omega}(q_t))}{1 - q_t g(\bar{\omega}(q_t))} - \frac{\bar{c}_t^e}{q_t} \tag{3.3.2.2}$$

Dividing through by $\eta$ (the mass of entrepreneurs), we get:

$$\bar{k}^e_{t+1} = \bar{n}_t \frac{f(\bar{\omega}(q_t))}{1 - q_t g(\bar{\omega}(q_t))} - \frac{\bar{c}_t^e}{q_t}$$

where $\bar{n}_t = w_t^e + \bar{k}^e_t [q_t(1 - \delta) + r_t]$ is average entrepreneurial net worth and $\bar{k}^e_t = K_t^e/\eta$ is the average stock of capital owned by entrepreneurs.

Maximising the entrepreneur’s utility in Equation (3.3.2.1) subject to the aggregate entrepreneurial capital stock in Equation (3.3.2.2) (see Appendix (3.5.3) for detailed derivation) gives the entrepreneur’s Euler equation:

$$q_t = \beta \gamma \mathbb{E}_t \left\{ [q_{t+1}(1 - \delta) + r_{t+1}] \frac{q_{t+1} f(\bar{\omega}_{t+1})}{1 - q_{t+1} g(\bar{\omega}_{t+1})} \right\}$$

The first term (in brackets) represents the market return on capital whilst the second term denotes the additional return on internal funds.
3.3.2.4 Capital Market Fund (CMF)/Bank

The CMF/Bank lends \((i_t(q_t, n_t) - n_t)\) consumption goods to each entrepreneur with net worth \(n_t\) (measured in consumption units). Let \(N_t\) denote aggregate entrepreneurial net worth. Since the investment function in Equation (3.3.1.8) is linear in net worth, aggregate lending is \(\left(\frac{q_t g(\bar{\omega}(q_t))}{1 - q_t g(\bar{\omega}(q_t))}\right) N_t\), denominated in terms of consumption units.

At the end of the period, \(\omega\) is realised for all firms and the expected proceeds from each individual entrepreneur is \(q_i(q_t, n_t) g(\bar{\omega}(q_t))\). Given that \(i(q_t, n_t)\) is linear in \(n_t\), this aggregates. Therefore, the total proceeds to the CMF/Bank are \(\frac{N_t}{1 - q_t g(\bar{\omega}(q_t))} q_t g(\bar{\omega}(q_t))\).

Comparing aggregate lending to total proceeds of the CMF/Bank, its profits are zero. This is because, in the optimal contracting problem, the lender’s participation constraint holds with equality.

3.3.2.5 Market Clearing Conditions

We close the model with the market-clearing conditions. The economy is characterised by four markets: two labour markets, a consumption-goods market, and a capital goods market.Labour market clearing for the consumption-goods sector ensures:

\[
H_t = (1 - \eta)L_t \\
H_t^e = \eta
\]

Consumption-good market clearing implies:

\[
(1 - \eta)c_t + \eta\bar{c}_t^e + \eta\bar{i}_t = Y_t
\]

where \(c_t\) is the representative household’s consumption, \(\bar{c}_t^e\) is average entrepreneurial consumption, and \(\bar{i}_t\) is average entrepreneurial investment. Finally, the capital goods market clearing implies:
\[ K_{t+1} = (1 - \delta)K_t + \eta \tilde{n}_t [1 - \mu \Phi(\tilde{\omega}_t)] \]

where aggregate capital \( K_t = (1 - \eta)k^h_t + \eta \bar{k}^e_t \) includes both household and entrepreneurial capital.

### 3.3.2.6 Recursive Competitive Equilibrium

A recursive competitive equilibrium consists of the following decision rules: \( k^h_{t+1}, \bar{k}^e_{t+1}, K_{t+1}, K^e_{t+1}, q_t, \tilde{n}_t, \tilde{i}_t, \tilde{\omega}_t, c^e_t, c_t, r_t, w_t, w^e_t, H_t, H^e_t, L_t, \) and \( Y_t \), such that these decision rules are stationary functions of \((K_t, K^e_t, A_t)\) and the following conditions are satisfied:

1. **Optimality conditions for household labour supply:**
   \[
   \frac{U_L(c_t, 1 - L_t)}{U_c(c_t, 1 - L_t)} = w_t
   \]

2. **Optimality conditions for household investment:**
   \[
   q_t U_c(c_t, 1 - L_t) = \beta E_t U_c(c_{t+1}, 1 - L_{t+1}) \left[q_{t+1}(1 - \delta) + r_{t+1}\right]
   \]

3. **Market clearing for capital good market:**
   \[ K_{t+1} = (1 - \delta)K_t + \eta \tilde{n}_t [1 - \mu \Phi(\tilde{\omega}_t)] \]

4. **Market clearing for consumption:**
   \[ (1 - \eta)c_t + \eta \bar{c}^e_t + \eta \tilde{n}_t = Y_t \]

5. **First Order Conditions defining \( \tilde{\omega}_t = \tilde{\omega}(q_t) \):**
   \[
   q_t \left[ 1 - \mu \Phi(\tilde{\omega}_t) + \mu \phi(\tilde{\omega}_t) \frac{f(\tilde{\omega}_t)}{f'(\tilde{\omega}_t)} \right] = 1
   \]

6. **Average investment \( \tilde{i}_t \) set optimally (given average net worth \( n_t \)):**
\[ \tilde{t}_t = i(q_t, \tilde{n}_t) = \frac{\tilde{n}_t}{1 - q_t g(\bar{\omega}_t)} \]

(7) Average entrepreneurial net worth \( \tilde{n}_t \):

\[ \tilde{n}_t = w^e_t + \bar{k}^e_t[q_t(1 - \delta) + r_t] \]

(8) Next period’s average entrepreneurial capital \( \bar{k}^e_{t+1} \):

\[ \bar{k}^e_{t+1} = \tilde{n}_t \frac{f(\bar{\omega}_t)}{1 - q_t g(\bar{\omega}_t)} - \frac{c^e_t}{q_t} \]

(9) Next period’s aggregate entrepreneurial capital \( K^e_{t+1} \):

\[ K^e_{t+1} = [\eta w^e_t + K^e_t(q_t(1 - \delta) + r_t)] \frac{f(\bar{\omega}(q_t))}{1 - q_t g(\bar{\omega}(q_t))} - \frac{\eta c^e_t}{q_t} \]

(10) First Order Conditions for entrepreneurial consumption:

\[ q_t = \beta \gamma E_t \left\{ [q_{t+1}(1 - \delta) + r_{t+1}] \frac{q_{t+1} f(\bar{\omega}_{t+1})}{1 - q_{t+1} g(\bar{\omega}_{t+1})} \right\} \]

(11) Aggregate capital:

\[ K_{t+1} = (1 - \eta)k^h_{t+1} + \eta \bar{k}^e_{t+1} \]

(12) Labour market clearing for the consumption-goods sector:

\[ H_t = (1 - \eta)L_t \]

\[ H^e_t = \eta \]

(13) Factor markets:
\[ r_t = A_t F_1(K_t, H_t, H_t^e) \]
\[ w_t = A_t F_2(K_t, H_t, H_t^e) \]
\[ w_t^e = A_t F_3(K_t, H_t, H_t^e) \]

3.3.3 Calibration and Results

We simulate and solve the model in Dynare (see Appendix (A.2) for details). To simulate the model, we first need to calibrate it. The calibration is at the non-stochastic steady state. As noted earlier, we assume that utility is logarithmic in consumption and linear in leisure. Following Carlstrom and Fuerst (1997), we choose \( \nu \), disutility of labour supply parameter, to be 2.52 so that \( L = 0.3 \). We normalise \( \eta \), fraction of entrepreneurs, to be 10%.

The Cobb-Douglas consumption-good producing technology has 36% as share of capital and 63.99% as share of household labour. Drawing on Carlstrom and Fuerst (1997) and Carlstrom and Fuerst (1998), we set as 0.01% the share of entrepreneurial labour. As stated earlier, this is also to, purposely, ensure that each entrepreneur always has positive level of net worth. The autocorrelation coefficient \( \rho_A \) of the stochastic aggregate productivity is set to 0.95 following standard RBC calibration. The non-stochastic steady state value of aggregate productivity \( A \) is set to 1 while we set the standard deviation of the innovation to aggregate productivity shock to \( \sigma_A = 1\% \).

In order to understand the impact of wealth redistribution in the economy, we consider a one-time shock to the distribution of wealth in the form of transfer of capital from entrepreneurs to households (lenders). To do this, we restate the net worth equation in the model bloc as \( \bar{n}_t = w_t^e + \bar{k}_t^e \left[ q_t (1 - \delta) + r_t \right] - \sigma_n \varepsilon_{n,t} \), where \( \varepsilon_{n,t} \) is a serially uncorrelated shock to the redistribution of wealth, and \( \sigma_n \) is the standard deviation of this shock.

There is enormous controversy over the verification cost parameter \( \mu \) (see Carlstrom and Fuerst (1997, 1998, 2001); Levin et al. (2004); De Fiore et al. (2011)) but
we set it to 0.15.

The distribution of the idiosyncratic productivity shock is \textit{i.i.d.} and follows a log-normal distribution, and as noted earlier, with mean 1 and standard deviation of \(\sigma_\omega\). Following Carlstrom and Fuerst (1997), we calibrate this standard deviation of the distribution of the idiosyncratic productivity shock to \(\sigma_\omega = 20.7\%\), and the steady-state additional discount rate for entrepreneurs to about \(\gamma = 91\%\) so as to generate a quarterly steady-state credit spread of about 0.5\% and a quarterly bankruptcy rate of about 1\%. We also calibrate \(\beta\) (the discount factor of households) to 0.99 to match a quarterly nominal interest rate of 1\%.

Table 3.3.3.1.: Calibration

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract Enforcement</td>
<td>(\zeta)</td>
<td>(0,1)</td>
</tr>
<tr>
<td>Verification Cost</td>
<td>(\mu)</td>
<td>0.15</td>
</tr>
<tr>
<td>Discount Factor</td>
<td>(\beta)</td>
<td>0.99</td>
</tr>
<tr>
<td>Labour Supply Disutility</td>
<td>(\nu)</td>
<td>2.52</td>
</tr>
<tr>
<td>Productivity Parameter</td>
<td>(A)</td>
<td>1.00</td>
</tr>
<tr>
<td>Persistence in Aggregate Technology Shock</td>
<td>(\rho_A)</td>
<td>0.95</td>
</tr>
<tr>
<td>Depreciation Rate of Capital</td>
<td>(\delta)</td>
<td>2%</td>
</tr>
<tr>
<td>Share of Capital in Production</td>
<td>(\alpha_K)</td>
<td>36%</td>
</tr>
<tr>
<td>Share of Entrepreneurial Labour in Production</td>
<td>(\alpha_e)</td>
<td>0.01%</td>
</tr>
<tr>
<td>Share of Household Labour in Production</td>
<td>(\alpha_H)</td>
<td>63.99%</td>
</tr>
<tr>
<td>Additional Discount Rate for Entrepreneurs</td>
<td>(\gamma)</td>
<td>91%</td>
</tr>
<tr>
<td>Fraction of Entrepreneurs</td>
<td>(\eta)</td>
<td>10%</td>
</tr>
<tr>
<td>Standard Deviation of (\Phi(\omega))</td>
<td>(\sigma_\omega)</td>
<td>20.7%</td>
</tr>
<tr>
<td>Standard Deviation of Net Worth Shock</td>
<td>(\sigma_n)</td>
<td>10%</td>
</tr>
<tr>
<td>Standard Deviation of Aggregate Productivity Shock</td>
<td>(\sigma_A)</td>
<td>1%</td>
</tr>
</tbody>
</table>

The recovery rate, \((1 - \zeta)\), is the fraction of capital that the lenders are able to recoup after a default is announced by the entrepreneurs. One presumes that this would depend positively on the strength of contract enforcement as determined by the quality of legal institutions. The better is the legal system the greater is the enforceability of contracts, and the larger is the recovery rate. Following Steinberg (2013), who calibrates the recovery rate to 23\% for an average country with limited enforcement, and the Doing Business index of World Bank (as used in Section (3.2)), we look at three scenarios of limited enforcement in our analysis. We calibrate \(\zeta\) to
70%, meaning a recovery rate, \((1 - \zeta)\), of 30% for an average country with limited enforcement, \(\zeta\) to 40%, indicating a recovery rate, \((1 - \zeta)\), of 60% for an average country with moderately good enforcement, and \(\zeta\) to 0 for an average country with perfect enforcement. The case of \(\zeta = 0\) coincides with agency costs models with no limited enforcement problems as in Carlstrom and Fuerst (1997) and Carlstrom and Fuerst (1998).

### 3.3.3.1 Aggregate Technology Shocks

Figures (3.3.3.1) and (3.3.3.3) show the impulse responses to a 1% positive aggregate technology shock for the baseline model, for three cases of limited enforcement (i.e. \(\zeta = 0\%\) (perfect enforcement), \(\zeta = 40\%\) (limited enforcement) and \(\zeta = 70\%\) (imperfect enforcement)). The positive productivity shock increases output, household consumption and net worth on impact. The increase in output and net worth results in an increased demand for capital which pushes the price of capital up. As the price of capital rises, the demand for investment falls which dampens the initial increase in output. As demand for investment falls, it boosts household consumption which in turn reduces household labour supply and dampens the increase in output. Though there is an increase in net worth, because the positive shock increases wages (including entrepreneurial wages) and rental income, the high price of capital makes the initial increase sluggish.

Increasing returns to entrepreneurial internal funds additionally increases net worth as the risk-neutral entrepreneur takes advantage of the rising price of capital by reducing their consumption. As the price of capital returns to its steady-state level, net worth attains its maximum before returning to the steady state. The increasing in demand for investment and value of net worth leads to an increase in demand for external funds. This pushes up the default threshold and the probability of default on impact of the shock. Following from the rise in the probability of default, lending rate rises on impact of the shock.
Figure 3.3.3.1.: Impulse responses from a positive technology shock. The vertical axis measures percentage deviations from the steady state. The horizontal axis measures time in quarters.
Additionally, the increase in value of internal funds, profit and the resulting increase in demand for external funds contributes to an increase in leverage.

The amplification effect of limited contract enforcement in the model is displayed by the three different lines corresponding to the different cases of contract enforceability. The growth in investment is dampened by limited enforcement. With higher degree of limited enforcement, the risk premium and the probability of default are much more sensitive to increases in borrowing. As displayed in Figure (3.3.3.2), increases in degree of limited enforcement ($\zeta$) results in an increase in the risk premium and a decrease in leverage. Figure (3.3.3.4) also shows that the rate of investment falls with the degree of limited enforcement.

Figure 3.3.3.2.: Relationship between expected leverage, expected risk premium and limited enforcement in response to productivity shocks.
Figure 3.3.3.3.: Impulse responses from a positive technology shock. The vertical axis measures percentage deviations from the steady state. The horizontal axis measures time in quarters.
Therefore, given a productivity shock, with higher degree of limited enforcement, it is more difficult for entrepreneurs to use their net worth to expand investment (hence the lower growth in investment in Figure (3.3.3.3)). Output responds to investment by displaying higher growth when the degree of limited enforcement is at its lowest level. When the degree of limited enforcement is at its highest level, the growth in output is at its lowest level. This reaction of aggregate output to the shock is consistent with the findings of Cooley et al. (2003) and Amaral and Quintin (2010). The negative effect of the limited enforcement on investment amplifies the increases in household consumption which in turn reduces household labour supply. The reduction in labour input is highest when the degree of limited enforcement is highest.

![Graph](image)

**Figure 3.3.3.4.** Relationship between expected investment and limited enforcement in response to productivity shocks.

As limited enforcement worsens, the price of capital rises. This is as a result of
the rise in risk premium and a fall in the supply of capital resulting from the dampened growth in investment. As a result of this rise in price of capital, both entrepreneurial capital and net worth increase the most when the degree of limited enforcement is highest. As earlier discussed, weak enforceability also exacerbates the effect of the shock on the probability of default, the lending rate and leverage. On impact of the shock, the probability of default rises by 2% when the degree of limited enforcement is 70% (i.e. when a firm can walk away with 70% of its output after default), 1% when the degree of limited enforcement is 40% (i.e. when a firm can walk away with 40% of its output after default) and 0.6% when there is “perfect” enforcement. The impact of the probability of default is reflected in the lending rate rising by 1.6%, 0.5% and 0.2%, respectively, when the degree of limited enforcement is 70%, 40% and 0%. As lending rate and net worth increase following an increase in the degree of enforcement, external funding is reduced resulting in leverage being lowest when the degree of limited enforcement is highest.

3.3.3.2 **Shocks to Net Worth**

Figures (3.3.3.5) and (3.3.3.7) display the impulse responses to a shock to net worth, for three cases of limited enforcement (i.e. $\zeta = 0\%$ (perfect enforcement), $\zeta = 40\%$ (limited enforcement) and $\zeta = 70\%$ (imperfect enforcement)). This shock will be a one-time transfer of capital from entrepreneurs to households (lenders). The redistribution is 20% of the steady-state capital stock. This transfer increases household capital and reduces entrepreneurial net worth. This reduction in entrepreneurial net worth raises the demand for external financing and thus raising agency costs of investment. The decrease in net worth reduces investment which in turn decreases the supply of capital, therefore raising the equilibrium price of capital. This decrease in investment also leads to higher household consumption which serves as an incentive for households to decrease their labour input.
Figure 3.3.3.5.: Impulse responses from a negative shock to net worth. The vertical axis measures percentage deviations from the steady state. The horizontal axis measures time in quarters.
The total impact is therefore a reduction in output. The decrease in value of net worth and demand for investment and the subsequent increase in demand for external funds increases the probability of default. Following the rise in the probability of default, lending rate rises. Additionally, the fall in the value of internal funds leads to an increase in demand for external funds which in turn contributes to an increase in leverage.

The amplification effect of limited contract enforcement in the model is displayed by the three different lines corresponding to the different cases of contract enforceability. As earlier argued, higher degree of limited enforcement results in the risk premium and the probability of default being more sensitive to increases in borrowing.

![Figure 3.3.3.6.](image)

**Figure 3.3.3.6.:** Relationship between expected leverage, expected risk premium and limited enforcement in response to net worth shocks.
Figure 3.3.3.7.: Impulse responses from a negative shock to net worth. The vertical axis measures percentage deviations from the steady state. The horizontal axis measures time in quarters.
As displayed in Figure (3.3.3.2), increases in degree of limited enforcement ($\zeta$) results in an increase in the risk premium and a decrease in leverage. Figure (3.3.3.4) also shows that the rate of investment falls with the degree of limited enforcement. A one-time wealth transfer to households instantaneously reduces net worth. Therefore, given a higher $\zeta$, it is even much more difficult for entrepreneurs to use their net worth to expand investment (hence the lower growth in investment in Figure (3.3.3.7)).

![Investment vs. Zeta](image)

**Figure 3.3.3.8.** Relationship between expected investment and limited enforcement in response to net worth shocks.

Output is at its lowest when the the degree of limited enforcement is at its highest level but highest when the degree of limited enforcement is lowest. The negative effect of the limited enforcement on investment further amplifies the increase in household consumption which in turn reduces household labour supply. The reduction in labour input is highest when the degree of limited enforcement is highest. The negative impact
of limited enforcement on both household labour supply and investment results in the effect of the shock on output being equally amplified. The fall in net worth, investment and output results in entrepreneurial capital also falling and attaining its lowest level when the degree of limited enforcement is highest.

As the degree of limited enforcement increases, the effect of the transfer on the probability of default, the lending rate and the degree of leverage is amplified. For instance, after the shock, the probability of default rises by 3.3% when the cost of enforcement is 70% (i.e. when a firm can walk away with 70% of its output after default), 2.5% when the cost of enforcement is 40% (i.e. when a firm can walk away with 40% of its output after default) and 2.5% when there is “perfect” enforcement. The impact of the probability of default is reflected in the lending rate rising by 3%, 1.1% and 0.7%, respectively, when the degree of limited enforcement is 70%, 40% and 0%. As lending rate increases and net worth decreases following an increase in the degree of limited enforcement, external funding is reduced resulting in the degree of leverage being lowest when the degree of limited enforcement is highest.

3.3.3.3 Sensitivity Analysis: Limited Enforcement, Output and Net Worth

In Table (3.3.3.2), following a positive productivity shock, an increase in the degree of limited enforcement, from 0% to 40%, is associated with a decrease in output volatility from 2.37% to 2.20% whilst an increase in the degree of limited enforcement from 0% to 70%, is associated with a decrease in output volatility from 2.37% to 2.05%. Similarly, expected output decreases as the degree of limited enforcement increases. In contrast, we find that as the degree of limited enforcement increases, expected net worth and its volatility follow similar trends. In a similar vein, expected lending rate and its volatility increase with the degree of limited enforcement. Our results are consistent with other studies (see Quintin (2000); Cooley et al. (2003)) which made similar findings on the

\(^{10}\) In the second quarter, for instance, the probability of default is 1.9%, 1% and 0.6% when the cost of enforcement is 70%, 40% and 0%, respectively.
impact of limited contract enforcement on output.

Table 3.3.3.2.: Productivity Shock

<table>
<thead>
<tr>
<th>Cost of Enforcement</th>
<th>Statistic</th>
<th>0%</th>
<th>40%</th>
<th>70%</th>
<th>0%</th>
<th>40%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Volatility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>1.01</td>
<td>1.00</td>
<td>0.99</td>
<td>2.37%</td>
<td>2.20%</td>
<td>2.05%</td>
<td></td>
</tr>
<tr>
<td>Net Worth</td>
<td>0.91</td>
<td>1.41</td>
<td>1.80</td>
<td>7.10%</td>
<td>10.36%</td>
<td>12.44%</td>
<td></td>
</tr>
<tr>
<td>Lending Rate</td>
<td>0.47%</td>
<td>1.36%</td>
<td>6.22%</td>
<td>0.11%</td>
<td>0.30%</td>
<td>1.16%</td>
<td></td>
</tr>
</tbody>
</table>

We measure volatility by standard deviations expressed in percentages.

Table (3.3.3.3) presents our findings following a one-time wealth transfer from entrepreneurs to households (lenders). One interesting finding in the data (see our empirical findings in Section (3.2)) is that countries with more limited contract enforcement tend to exhibit more volatility in output. Result from our model with one-time wealth transfer is able to reproduce this observation. Whist expected output decreases, volatility of output increases as the degree of limited enforcement increases. Similarly, both expected net worth and its volatility increase as the degree of limited enforcement increases. Things are not different when it comes to the lending rate. Expected lending rate and its volatility increase as the degree of limited enforcement rises.

This result may be seen as being especially pertinent for the case of small firms that use their net worth as collateral and rely largely on external finance for production. New entrants and smaller firms may be credit constrained and find the cost of loans expensive as the degree of limited enforcement increases. The result suggests that limited contract enforcement may be particularly an issue for the growth of such firms and, with this, the growth of the economy as a whole, as argued by Amaral and Quintin (2010) and Albuquerque and Hopenhayn (2000).

3.3.3.4 Sensitivity Analysis: Welfare Consequences of Limited Contract Enforcement

A very important issue worth commenting on is the effect of limited enforcement on household welfare, the presumption being that weaker enforcement reduces welfare.
Table 3.3.3.: One-Time Wealth Transfer

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Cost of Enforcement</th>
<th>Mean</th>
<th>Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>0%</td>
<td>1.01</td>
<td>2.28%</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>1.00</td>
<td>2.32%</td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>0.99</td>
<td>2.19%</td>
</tr>
<tr>
<td>Net Worth</td>
<td>0%</td>
<td>0.91</td>
<td>18.49%</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>1.41</td>
<td>18.46%</td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>1.80</td>
<td>18.92%</td>
</tr>
<tr>
<td>Lending Rate</td>
<td>0%</td>
<td>0.47%</td>
<td>0.36%</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>1.36%</td>
<td>0.62%</td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>6.22%</td>
<td>1.87%</td>
</tr>
</tbody>
</table>

We measure volatility by standard deviations expressed in percentages.

Following Lucas (1987), we estimate welfare loss (consumption equivalent) as the percentage decrease in households consumption in the economy with perfect enforcement which makes households indifferent between the economy with limited enforcement and the economy perfect enforcement (see Appendix (3.5.5) for detailed derivation of welfare loss). In the context of the present model, when enforceability is poor, investment responds positively. In light of this, in response to a positive productivity shock, households consumption increases which results in household labour supply falling. This leads to household welfare increasing accordingly. However, the initial increase in welfare is dampened when enforcement worsens. The result displayed in Table (3.3.3.4) provides an additional support for the effect of limited enforcement on household welfare, when there is a positive productivity shock. The result shows that as the degree of limited enforcement increases from 40% to 70%, the average household consumption equivalent welfare loss increases from 0.86% to 1.84%.

Table 3.3.3.4.: Welfare loss

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Cost of Enforcement</th>
<th>40%</th>
<th>70%</th>
<th>40%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption Equivalent of Welfare Loss</td>
<td>productivity shock</td>
<td>0.86%</td>
<td>1.84%</td>
<td>0.9%</td>
<td>1.89%</td>
</tr>
</tbody>
</table>

Welfare consequences of productivity shock and one-time wealth transfer

In response to a one-time transfer of wealth from entrepreneurs to households, consumption of the latter increases which then results in labour supply falling. This leads to household welfare increasing, on impact of the shock. However, as the the transfer is one-time the initial increase in welfare is short-lived. In Table (3.3.3.4) we
present the results of the impact of the wealth transfer on households. We show that as the degree of limited enforcement increases from 40% to 70%, the average consumption equivalent welfare loss increases from 0.9% to 1.89%.

3.3.3.5 Limited Enforcement, Monitoring Cost and Output

Table (3.3.3.5) displays the effect of changes in monitoring cost and the degree of limited enforcement on output.

### Table 3.3.3.5.: Effect of Limited Enforcement and Monitoring Cost on Output

<table>
<thead>
<tr>
<th>Degree of Enforcement</th>
<th>Monitoring and Verification Cost</th>
<th>Percentage Change in Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mu = 5%$</td>
<td>$\mu = 10%$</td>
</tr>
<tr>
<td>$\zeta = 0%$</td>
<td>1.82%</td>
<td>1.71%</td>
</tr>
<tr>
<td>$\zeta = 40%$</td>
<td>0.90%</td>
<td>0.89%</td>
</tr>
<tr>
<td>$\zeta = 70%$</td>
<td>-0.42%</td>
<td>-0.19%</td>
</tr>
</tbody>
</table>

Smaller $\mu$ means better credit information. Smaller $\zeta$ means better contract enforcement. Percentage change in output relative to the steady state output when $\zeta = 70\%$

It is observed that as monitoring cost fall (i.e. as credit information improves), its effect on output increases. Similarly, as enforcement improves, its impact on output increases. This findings is consistent with our empirical result, particularly, where we establish that both poor depth of credit information and limited enforcement have negative effect on output.

3.4 Concluding Remarks

This paper has presented a dynamic stochastic general equilibrium model of asymmetric information and limited contract enforcement in financial markets. The first of these features—a fairly standard way of incorporating capital market frictions into macroeconomic models—is reflected in the idea of costly state verification by financial intermediaries. The second feature—a much less standard way of capturing such frictions—is reflected in the notion of institutional weaknesses in holding defaulters to
account. It is this second aspect on which our interest has been focused and in which the contribution of the analysis is mainly found.

We have shown how limited contract enforcement may affect fluctuations in key macroeconomic variables (e.g. output, employment and investment) through its impact on key financial variables (e.g. interest rates, risk premium, default risk and leverage). Our results are particularly relevant for developing countries, where institutions are often weak, fragile and fragmented because of poor quality of governance. Our analysis suggests that improving such quality has the potential to improve the prospects of such countries.
3.5 Appendix A

3.5.1 Household Optimisation Problem

Households maximise expected life time utility

$$\mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t U(c_t, (1 - L_t)) \right]$$

subject to

$$c_t + q_t \left[ k_{t+1}^h - (1 - \delta) k_t^h \right] = w_t L_t + r_t k_t^h$$

where $U(c_t, (1 - L_t)) = \ln(c_t) + \nu(1 - L_t)$

Lagrange for the problem:

$$\mathcal{L} = \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \left[ \ln(c_t) + \nu(1 - L_t) \right] \right]$$

$$+ \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \left[ \lambda_t w_t + r_t k_t^h - c_t - q_t \left( k_{t+1}^h - (1 - \delta) k_t^h \right) \right] \right]$$

First Order Conditions from household maximisation problem:

$$c : U_c(c_t, 1 - L_t) - \lambda_t = 0 \quad (3.5.1.1)$$

$$k_{t+1}^h : -q_t \lambda_t + \beta \mathbb{E}_t \left[ \lambda_{t+1} \left( r_{t+1} + q_{t+1}(1 - \delta) \right) \right] = 0 \quad (3.5.1.2)$$

$$L : U_L(c_t, 1 - L_t) + \lambda_t w_t = 0 \quad (3.5.1.3)$$

Equation (3.5.1.3) implies $\lambda_t = \frac{\nu}{w_t}$

Note that $U_c(c_t, 1 - L_t) = c_t^{-1}$; $U_L(c_t, 1 - L_t) = -\nu$. Then

$$w_t = \frac{U_L(c_t, 1 - L_t)}{U_c(c_t, 1 - L_t)} = \frac{\nu}{c_t^{-1}} \quad (3.5.1.4)$$

Equation (3.5.1.4) implies:

$$c_t = \left( \frac{\nu}{w_t} \right)^{-1} = \left( \frac{w_t}{\nu} \right)$$
Using Equations (3.5.1.1) and (3.5.1.2) we can write the Euler Equation as:

\[ q_t U_c(c_t, 1 - L_t) = \beta \mathbb{E}_t [U_c(c_{t+1}, 1 - L_{t+1}) (r_{t+1} + q_{t+1}(1 - \delta))] \]  \hspace{1cm} (3.5.1.5)

Equation (3.5.1.5) is then simplified as:

\[ q_t c_t^{-1} = \beta \mathbb{E}_t [c_{t+1}^{-1} (r_{t+1} + q_{t+1}(1 - \delta))] \]

### 3.5.2 Consumption-good Producing Firms

We specify the production function as:

\[ Y_t = A_t K_t^{\alpha_K} H_t^{\alpha_H} e^{e_t} \]

Perfect competition in factor markets implies the following factor prices:

\[ r_t = A_t F_1(K_t, H_t, H_t^e) = \alpha_K A_t K_t^{\alpha_K - 1} H_t^{\alpha_H} e^{e_t} = \frac{Y_t}{K_t} \]

\[ w_t = A_t F_2(K_t, H_t, H_t^e) = \alpha_H A_t K_t^{\alpha_K} H_t^{\alpha_H - 1} e^{e_t} = \frac{Y_t}{H_t} \]

\[ w_t^e = A_t F_3(K_t, H_t, H_t^e) = \alpha_e A_t K_t^{\alpha_K} H_t^{\alpha_H} e^{e_t-1} = \frac{Y_t}{H_t^e} \]

### 3.5.3 The Entrepreneur

Entrepreneurs maximise their expected life time utility

\[ \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} (\beta \gamma)^t c_t^e \right] \]  \hspace{1cm} (3.5.3.1)

subject to
\[ K_{t+1}^e = (\eta w_t^e + K_t^e [q_t(1 - \delta) + r_t]) - \frac{f(\bar{\omega}(q_t))}{1 - q_t g(\bar{\omega}(q_t))} - \frac{c_t^e}{q_t} \] (3.5.3.2)

Lagrange for the problem:

\[
\mathcal{L} = E_0 \sum_{t=0}^\infty \beta^t (c_t^e) + E_0 \sum_{t=0}^\infty \beta^t \left[ \lambda_t \left( (\eta w_t^e + K_t^e [q_t(1 - \delta) + r_t]) - \frac{f(\bar{\omega}(q_t))}{1 - q_t g(\bar{\omega}(q_t))} - \frac{c_t^e}{q_t} - K_t^e \right) \right]
\]

\[ c_t^e : u_{\omega}(t) - \lambda_t/q_t = 0 \]

\[ \lambda_t = q_t \]

\[ K_{t+1}^e : -\lambda_t + (\beta \gamma) E_t \{ \lambda_{t+1} (q_{t+1}(1 - \delta) + r_{t+1}) - \frac{f(\bar{\omega}(q_{t+1}))}{1 - q_{t+1} g(\bar{\omega}(q_{t+1}))} \} = 0 \]

\[ q_t = (\beta \gamma) E_t \left[ (q_{t+1}(1 - \delta) + r_{t+1}) - \frac{q_{t+1} f(\bar{\omega}(q_{t+1}))}{1 - q_{t+1} g(\bar{\omega}(q_{t+1}))} \right] \] (3.5.3.3)

3.5.4 Optimal contract

The optimal contract is given by the pair \((i, \bar{\omega})\) (taking as given net worth \(n\) and capital price \(q\)) which solves:

\[
\max_{i, \bar{\omega}} q i f(\bar{\omega})
\]

subject to

\[ q i g(\bar{\omega}) \geq i - n \text{ Lender’s Participation constraint} \]

\[ q i f(\bar{\omega}) \geq n \text{ Entrepreneur’s Participation constraint, always satisfied} \]

Technically, only the first constraint binds.

Lagrangian for this problem:
\[ L = q_i f(\bar{\omega}) + \lambda [q_i g(\bar{\omega}) - i + n] \]

The First Order Conditions:

\[
\begin{align*}
\frac{\partial L}{\partial i} &= q_i f(\bar{\omega}) + \lambda [q_i g(\bar{\omega}) - 1] = 0 \quad (3.5.4.1) \\
\frac{\partial L}{\partial \bar{\omega}} &= q_i f'(\bar{\omega}) + \lambda q_i g'(\bar{\omega}) = 0 \quad (3.5.4.2) \\
\frac{\partial L}{\partial \lambda} &= q_i g(\bar{\omega}) - i + n = 0 \quad (3.5.4.3)
\end{align*}
\]

Re-arranging Equation (3.5.4.1):

\[
q \left[ \frac{1}{\lambda} f(\bar{\omega}) + g(\bar{\omega}) \right] = 1
\]

\[
\lambda = -\frac{f'(\bar{\omega})}{g'(\bar{\omega})}
\]

Then, re-arranging Equation (3.5.4.2), we get

\[
1 = \frac{g'(\bar{\omega})}{-f'(\bar{\omega})} = \frac{(1 - \zeta)(1 - \Phi(\bar{\omega})) - \mu \phi(\bar{\omega})}{(1 - \zeta)(1 - \Phi(\bar{\omega}))} = 1 - \frac{\mu \phi(\bar{\omega})}{(1 - \zeta)(1 - \Phi(\bar{\omega}))}
\]

Then, combined with Equation (3.3.1.6), we have the following condition:

\[
q \left[ 1 - \mu \Phi(\bar{\omega}) - \frac{\mu \phi(\bar{\omega}) f(\bar{\omega})}{(1 - \zeta)(1 - \Phi(\bar{\omega}))} \right] = 1 \quad (3.5.4.4)
\]

This can also be written as:

\[
q \left[ 1 - \mu \Phi(\bar{\omega}) + \mu \phi(\bar{\omega}) \frac{f(\bar{\omega})}{f'(\bar{\omega})} \right] = 1
\]

### 3.5.5 Consumption Equivalent Welfare Loss

Let \( \lambda \) denote consumption equivalent welfare loss, the fraction of consumption one would be willing to give up each period in the economy with perfect enforcement.
\[ \mathbb{E}(V_t^{\text{perfect enforcement}}(\lambda)) = \mathbb{E}\left[ (\ln(c_t(1 + \lambda)) + \nu(1 - L_t)) + \beta \mathbb{E}_t\left[ V_{t+1}^{\text{perfect enforcement}} \right] \right] \]

\( \lambda \) shows up every period and we assume it is deterministic and this reduces to:

\[ \mathbb{E}(V_t^{\text{perfect enforcement}}(\lambda)) = \frac{1}{1 - \beta}(1 + \lambda) + \mathbb{E}\left[ (\ln(c_t) + \nu(1 - L_t)) + \beta \mathbb{E}_t\left[ V_{t+1}^{\text{perfect enforcement}} \right] \right] \]

The term in brackets is then:

\[ \mathbb{E}(V_t^{\text{perfect enforcement}}(\lambda)) = \frac{1}{1 - \beta}(1 + \lambda) + \mathbb{E}(V_t^{\text{perfect enforcement}}) \]

Then we want to find the \( \lambda \) that equates this with expected welfare in an economy with limited enforcement. We have:

\[ \mathbb{E}(V_t^{\text{perfect enforcement}}(\lambda)) = \mathbb{E}(V_t^{\text{limited enforcement}}) \]

Or

\[ \frac{1}{1 - \beta}(1 + \lambda) + \mathbb{E}(V_t^{\text{perfect enforcement}}) = \mathbb{E}(V_t^{\text{limited enforcement}}) \]

Then

\[ \lambda = \exp\left[ (1 - \beta) \times (\mathbb{E}(V_t^{\text{limited enforcement}}) - \mathbb{E}(V_t^{\text{perfect enforcement}})) \right] - 1 \]

If we take the economy with perfect enforcement to have higher welfare, then \( \lambda < 0 \). This means you would be willing to give up consumption in the high welfare economy to have the same welfare as an economy with lower welfare (limited enforcement).

### 3.5.6 Steady State

The steady state of the model is characterised by:
\[ q^{ss} = \frac{1}{1 - \mu \Phi^{ss} + \bar{\omega}^{ss} \omega^{ss} \mu f^{ss}} \]
\[ q^{ss} = \frac{1 - (\beta \gamma) r^{ss} f^{ss}}{[(\beta \gamma) f^{ss}(1 - \delta) + g^{ss}]} \]
\[ Y^{ss} = A^{ss} K^{ss} K H^{ssa} H^{ssalpha} \]
\[ YK^{ss} = Y^{ss} / K^{ss} \]
\[ r^{ss} = \alpha_K YK^{ss} \]
\[ w^{ss} = \alpha_H Y^{ss} / H^{ss} \]
\[ w^{ess} = \alpha_e Y^{ss} / H^{ess} \]
\[ YK^{ss} = \frac{1}{\alpha_K} \left[ \frac{1 - q^{ss} g^{ss}}{\gamma \beta f^{ss}} - q^{ss} (1 - \delta) \right] \]

We calibrate \( \gamma \) such that the steady state internal return is \( \frac{\gamma q^{ss} f^{ss}}{1 - q^{ss} g^{ss}} = 1 \). Then \( YK^{ss} \) becomes

\[ YK^{ss} = \frac{1}{\alpha_K} \left[ \frac{q^{ss}}{\beta} - q^{ss} (1 - \delta) \right] \]
\[ K^{ss} = \left( \frac{YK^{ss}}{A^{ss} H^{ssalpha} H^{essalpha}} \right)^{1/\alpha_K - 1} \]
\[ C^{ss} = \eta c^{ess} + (1 - \eta) c^{ss} \]
\[ C^{ss} / Y^{ss} = CY^{ss} \]
\[ CY^{ss} = 1 - \frac{\delta}{YK^{ss}} (1 - \Phi^{ss} \mu) \]
\[ l^{ss} = \frac{\delta K^{ss}}{(1 - \Phi^{ss} \mu)} \]
\[ n^{ss} = (1 - q^{ss} g^{ss}) \frac{\delta K^{ss}}{(1 - \Phi^{ss} \mu)} \]
\[ k^{ess} = \frac{\bar{n}^{ss} - \eta w^{ess}}{(q^{ss}(1 - \delta) + r^{ss})} = \frac{\beta}{q^{ss}} (\bar{n}^{ss} - \eta w^{ess}) \]
\[\nu = w^{ss} c^{ss(-1)}\]

\[c^{ess} = \frac{d^{ss}(f^{ss} - \bar{k}^{ess})}{\eta}\]

\[c^{ss} = C Y^{ss} Y^{ss}\]

\[\phi^{ss} = \phi(\bar{\omega}^{ss})\]

\[\Phi^{ss} = \Phi(\bar{\omega}^{ss})\]

\[f^{ss} = f(\bar{\omega}^{ss})\]

\[g^{ss} = g(\bar{\omega}^{ss})\]

\[f'^{ss} = f'(\bar{\omega}^{ss})\]
3.6 Appendix B

3.6.1 Tables

Table 3.6.1.1.: Countries for Empirical Work

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Table 3.6.1.2.: Continuation of Countries for Empirical Work

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We used data for 57 countries

Table 3.6.1.3.: Summary statistics

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3.6.2 Figures

Figure 3.6.2.1.: Scatter: Standard Deviation of GDP and Contract Enforcement
Table 3.6.1.4.: Fixed and Random Effects Regression for Full Sample (57 Countries)

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Time and Country FE and RE
Standard errors in brackets

* p<10%, ** p<5%, *** p<1%
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**Table 3.6.1.6.:** Fixed and Random Effects Regression (34 Countries)

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Time and Country FE and RE
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Table 3.6.1.7.: Fixed and Random Effects Regression (34 Countries)

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Country FE and RE
Standard errors in brackets
* p<10%, ** p<5%, *** p<1%
This thesis explores the broad issue of the effects of institutions on macroeconomic performance. The study of the relationship between institutions including the operations of financial markets, and economic performance has a long history in economics (see Beck and Levine (2008)). The importance of well-functioning institutions has been widely documented and is generally accepted (see Knack and Keefer (1995); Rodrik et al. (2004); Hall and Jones (1999a)). Rodrik et al. (2004) and Hall and Jones (1999a) observe that good quality institutions is one of the most important factors in raising per capita output and promoting economic development. Against this background, we study two areas of institutional imperfection—limited governance of corruption and limited enforcement of financial contracts. We do so in two main chapters, a brief summary of each of which is given below.

In the first chapter we study the effects of corruption on sovereign debt decisions. First, we empirically investigate the determinants of sovereign default. Using various specifications we find that political stability and corruption increase sovereign default risk. Second, we setup a dynamic stochastic general equilibrium model to investigate theoretically the effects of corruption and political risk on sovereign default decisions, and the implications for macroeconomic activity. Consistent with our empirical results, we find that corruption can generate high default risk and high credit spreads, but only when there is enough political stability. In the stable economy with political turnover, the less corrupt policymakers choose debt levels that would induce a more corrupt
policymaker to default. This results in higher credit spreads and higher overall default rates compared to the case of no turnover or less stability. A seemingly intuitive result is that a change in power from a less corrupt to a more corrupt government leads to a greater likelihood of default. This is because of the high level of borrowing by a less corrupt government, which saddles the more corrupt government with high levels of debt on which it is induced to default. Our analysis also demonstrates the amplification effects of corruption on macroeconomic fluctuations, together with the negative effects of corruption on welfare.

In the second main chapter we study limited contract enforcement in financial markets and the impact of this on firm financing and aggregate outcomes. As a motivation, we empirically investigate the effects of limited contract enforcement on output using panel data. We find that limited enforcement has a negative effect on output and that this effect is inhibited by poor credit information, although poor credit information has negative effect on output. We also find that high costs of contract enforcement are associated with high output volatility. We then present a dynamic stochastic general equilibrium model of asymmetric information and limited contract enforcement to study the issue theoretically. We show that limited enforcement has effect on a number of finance variables, such as the leverage of firms, the lending rate and the risk premium. These effects, all of which are positive, are due to the higher probability of default when contract enforcement is weaker. An implication is that firms are subject to tighter credit constraints, the impact of which is most significant for relatively small firms. Through these channels, we demonstrate how limited enforcement affects macroeconomic variables, such as output, employment and price. Consistent with our empirical observations, we find that a higher cost of contract enforcement is associated with a greater volatility of output.

On the whole, our results indicate that imperfectly-functioning institutions tend to impede on macroeconomic performance. These results are particularly relevant for developing countries, where institutions are often weak, fragile and fragmented because of poor quality of governance. Our analysis suggests that improving such quality has
the potential to improve the prospects of such countries.

The current study is limited in many respects. The inability to find suitable instrumental variables to solve a possible endogeneity problem, in the empirical work of Chapter (2), is a limitation to the study. In Chapter (2), though the empirical study could not make use of all possible control variables, the study could still face limitation for not including for instance external factors as controls. Also, including more control variables, in the empirical work of the thesis, could enrich our empirical findings. Though the current study has enriched our understanding of institutions and macroeconomic performance, possible effects of institutions on key macroeconomic variables such as monetary policy has not been adequately addressed. The existing models on institutions (see Huang and Wei (2003, 2006)) find that weak institutions do not only make monetary policy ineffective but also have serious consequences for monetary policy targets. We recommend that our model on corruption and sovereign default be extended to incorporate the monetary policy sector. By this we will be able to study monetary and fiscal policy interactions in a weak institutional setting and their consequence on macroeconomic outcomes. Incorporating monetary policy into the model on limited contract enforcement will improve our understanding of how effective or ineffective monetary policy will be under limited contract enforcement. Also introducing habit formation into the utility function will smooth consumption and enable us understand the behaviour of households towards consumption, in the present context.
BIBLIOGRAPHY


Appendix A

Computer Codes

A.1 Chapter 2 Computer Codes

A.1.1 STATA CODES

This Stata code is used for the empirical results of this chapter of the thesis.

Listing A.1: Stata Do File

//import data
//use sovereign.dta", clear
egen id = group(country)
xtset id year

//icrgc= measure of corruption
//prr = measure political stability
//lgdppc= log GDP per capita
//gdpgww= GDP growth
//extdebtperc= external debt–GDP ratio
//def= default

//icrgcl= one period lag of corruption
//prrl = one period lag of political stability
//lgdppcl= one period lag of log GDP per capita
//gdpgwwl= one period lag of GDP growth
//extdebtpercl= one period lag of external debt–GDP ratio
//defl= one period lag of default

//CORRELATIONS
corrtec def icrgc prr lgdppc gdpgww extdebtperc,

//SUMMARY STATISTICS
sutex def icrgc prr lgdppc gdpgww extdebtperc,minmax
/CURRENT EXPLANATORY VARIABLES ONLY
prob def icrgc prr extdebtperc gdpgww
eststo PROB1
prob def icrgc prr extdebtperc lgdppc
eststo PROB2
prob def icrgc prr extdebtperc gdpgww lgdppc
eststo PROB3
//mfx
prob def icrgc prr extdebtperc gdpgww
mfx
eststo mfx1
prob def icrgc prr extdebtperc lgdppc
mfx
eststo mfx2
prob def icrgc prr extdebtperc gdpgww lgdppc
mfx
eststo mfx3
//WITH LAGGED DEFAULT
prob def def1 icrgc1 prr1 extdebtperc1 gdpgww1
eststo PROB1
prob def def1 icrgc1 prr1 extdebtperc1 lgdppc1
eststo PROB2
prob def def1 icrgc1 prr1 extdebtperc1 gdpgww1 lgdppc1
eststo PROB3
prob def def1 icrgc1 prr1 extdebtperc1 gdpgww1
mfx
eststo mfx1
prob def def1 icrgc1 prr1 extdebtperc1 lgdppc1
mfx
eststo mfx2
prob def def1 icrgc1 prr1 extdebtperc1 gdpgww1 lgdppc1
mfx
eststo mfx3
//ONLY LAGGED EXPLANATORY VARIABLES; NO LAGGED DEFAULT

prob def icrgc1 prrl extdebtpercl gdpgwwl eststo PROB1

prob def icrgc1 prrl extdebtpercl lgdppec1 eststo PROB2

prob def icrgc1 prrl extdebtpercl gdpgwwl lgdppec1 eststo PROB3

//MFX

prob def icrgc1 prrl extdebtpercl gdpgwwl mfx eststo mfx1

prob def icrgc1 prrl extdebtpercl lgdppec1 mfx eststo mfx2

prob def icrgc1 prrl extdebtpercl gdpgwwl lgdppec1 mfx eststo mfx3
A.1.2 FORTRAN CODES

We use fortran to solve the theoretical model by value function iteration. corruption-model.f90 is the main program which drives the value function iteration (vfi_module.f90) and the simulation (sim_module.f90). The code makes use of the fortran library (function) alnorm by Hill (1973) to compute the cumulative density function of the standard normal distribution (https://people.sc.fsu.edu/~jburkardt/f77_src/asa066/asa066.html for code). To run these programs we also need other modules which include:

i. grid_construction.f90 which constructs the grids for the programs.
ii. model_tools.f90 which creates and save the parameters for solving the programs.
iii. data_output.f90, a module for saving data from the programs.
iv. array_tools.f90 for sorting arrays and array structures.
v. input_param.txt; this contains the parameter values to be used by the various programs.

Listing A.2: Value Function Iteration

module vfi_module
    use model_tools
    use omp_lib
    implicit none

    type solution_vars
        real(8) :: val            ! optimal value
        real(8) :: bn_sol         ! b’ choice
        integer :: bn_sol_idx     ! index for b’
        real(8) :: c_sol          ! consumption choice
    end type solution_vars

    contains

    !******************************************************************************!
    ! subroutine val_fcn_iter
    !******************************************************************************!
subroutine val_fcn_iter(n_b, n_y, b_grid, y_grid, Py, & 
   Py_cdf,pm, q, p_d, ystar, d_policy, c_policy, & 
   bn_policy, bn_idx_policy)

implicit none

integer, intent(in) :: n_b, n_y
real(8), dimension(n_b), intent(in) :: b_grid
real(8), dimension(n_y), intent(in) :: y_grid
real(8), dimension(n_y, n_y), intent(in) :: Py
real(8), dimension(n_y, n_y), intent(in) :: Py_cdf

! policy functions (output)
real(8), dimension(n_b,n_y,2,2), intent(out) :: q
! q(b',y,d,type), q schedule
real(8), dimension(n_b,n_y,2,2), intent(out) :: p_d
! p_d(b',y,h',type'), default probability
integer, dimension(n_b,2,2), intent(out) :: ystar
! y*(b',h',type'), default thresholds
logical, dimension(n_b,n_y,2,2), intent(out) :: d_policy
! d(b,y,hist,type), default policy
real(8), dimension(n_b,n_y,2,2), intent(out) :: c_policy
! d(b,y,hist,type), default policy
real(8), dimension(n_b,n_y,2,2), intent(out) :: bn_policy
! b '(b,y,hist,type), debt policy
integer, dimension(n_b,n_y,2,2), intent(out) :: bn_idx_policy
! b '(b,y,hist,type), debt policy (index)

! %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
! local arrays
! %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
! make allocatable, to avoid memory problems
real(8), allocatable, dimension(:, :, :, :) :: v, v0
! v(b,y,h,type)
real(8), allocatable, dimension(:, :, :, :) :: vhat, vhat0
! vhat(b,y,h,type)
real(8), allocatable, dimension(:, :, :) :: vd, vd0
! v_d(y,h,type), value of default
real(8), allocatable, dimension(:, :, :) :: vnd, vnd0
! \texttt{v\_nd(b,y,h,type)}, value of not defaulting
real(8), allocatable, dimension(:,:,:,:) :: cv
! \texttt{cv(b',y,d,type)}, continuation values

! local variables
integer, parameter :: MAX\_ITER = 1000
real(8), parameter :: TOL = 1.0d-6
real(8) :: err\_v, err\_vhat
integer :: iter, eflag
integer :: i\_b, i\_y, i\_type, i\_h
logical :: def
type(solution\_vars) :: sol\_nd, sol\_d

! Allocate local arrays
allocate ( v(n\_b,n\_y,2,2), v0(n\_b,n\_y,2,2), &
         vhat(n\_b,n\_y,2,2), vhat0(n\_b,n\_y,2,2) )
allocate ( vnd(n\_b,n\_y,2,2), vnd0(n\_b,n\_y,2,2) )
allocate ( vd(n\_y,2,2), vd0(n\_y,2,2) )
allocate ( cv(n\_b,n\_y,2,2) )

! initialize iteration
eflag = 0
iter = 0

! initialize value functions
call init\_vfi(n\_b, n\_y, pm, v0, vnd0, vd0, vhat0)

do while ( eflag == 0)

! compute bond price schedule, default cutoffs and prob of
! default
call calc\_bond\_price\_schedule(n\_b, n\_y, vnd0, vd0,&
Py\_cdf,pm, q, p\_d, ystar)

! compute continuation values, CV(b',y,d,j)
! b' == debt choice, y = current y, d = default choice today,
! j = type today
call calc\_cv(n\_b, n\_y, v0, vhat0, Py, pm, cv)
then compute optimal choices, update vd, vnd, v and policy rules

loop over y first to take advantage of OpenMP

!omp parallel do private (i_type, i_h, i_y, i_b, def,&
   sol_d, sol_nd)
do i_y = 1, n_y    ! endowment y
do i_type = 1, 2    ! gov type, currently in power
do i_h = 1, 2       !! current history h

! compute value of defaulting
   def = .true.
   i_b = 1
! set i_b = 1 (sovereign is defaulting anyway)
call solve_gridsearch(n_b, n_y, i_b, i_y, i_h,&
   i_type, def, b_grid, y_grid, q, cv, pm, sol_d)

vd(i_y, i_h, i_type) = sol_d%val

do i_b = 1, n_b   ! debt/assets b

! compute value of not defaulting
   def = .false.
call solve_gridsearch(n_b, n_y, i_b, i_y,&
   i_h, i_type, def, b_grid, y_grid, q, cv,&
   pm, sol_nd)

vnd(i_b, i_y, i_h, i_type) = sol_nd%val

if (sol_nd%val >= sol_d%val) then
   d_policy(i_b, i_y, i_h, i_type) =&
     .false.
c_policy(i_b, i_y, i_h, i_type) =&
     sol_nd%c_sol
bn_policy(i_b, i_y, i_h, i_type) =&
     sol_nd%bn_sol
bn_idx_policy(i_b, i_y, i_h, i_type)&
   = sol_nd%bn_sol_idx
v(i_b, i_y, i_h, i_type) = &
     sol_nd%val
else
    
    d_policy(i_b, i_y, i_h, i_type) = .true.
    c_policy(i_b, i_y, i_h, i_type) = &
        sol_d%c_sol
    bn_policy(i_b, i_y, i_h, i_type) =&
        sol_d%bn_sol
    bn_idx_policy(i_b, i_y, i_h, &
        i_type) = sol_d%bn_sol_idx
    v(i_b, i_y, i_h, i_type) =&
        sol_d%val
    
end if

end do
end do
end do
end do
!$omp end parallel do

! now update value when not in government
call update_vhat(n_b, n_y, Py, v0, vhat0, d_policy,&
    c_policy, bn_idx_policy, pm, vhat)

! compute convergence error
err_v = maxval( abs(v - v0) / abs(v0) );
err_vhat = maxval( abs(vhat - vhat0) / abs(vhat0) );

if (mod(iter, 10) == 0) then
    print *, "iter = ", iter, " err = ", max( err_v, &
        err_vhat )
end if

! all returns true if all elements in the array are true
if ( all( abs(v-v0) <= TOL*abs(v0) ) .and. all(&
    abs(vhat-vhat0) <= TOL*abs(vhat0) ) ) then
    eflag = 1;
end if

iter = iter + 1;
if (iter >= MAX_ITER) then
    print *, "Maximum Iterations Reached"
    eflag = 2;
end if

! update guess
v0 = v;
vd0 = vnd
vd0 = vd
vhat0 = vhat

end do

! save results
call save_vfi_results(n_b, n_y, b_grid, y_grid, v, vnd,&
                        vd, vhat, d_policy, c_policy, q, bn_policy)

end subroutine val_fcn_iter

******************************************************************************
! subroutine init_vfi
******************************************************************************
subroutine init_vfi(n_b, n_y, pm, v0, vnd0, vd0, vhat0)
implicit none

integer, intent(in) :: n_b, n_y
type(params), intent(in) :: pm

real(8), dimension(n_b,n_y,2,2), intent(out) :: v0
real(8), dimension(n_b,n_y,2,2), intent(out) :: vnd0
real(8), dimension(n_y,2,2), intent(out) :: vd0
real(8), dimension(n_b,n_y,2,2), intent(out) :: vhat0

logical :: load_initial_guess
integer :: in_file = 109

load_initial_guess = (.not. pm%new_v0)

if (load_initial_guess) then
open(in_file, file = "results/guess_v0.txt")
read (in_file,*) v0
rewind(in_file)
close(in_file)

open(in_file, file = "results/guess_vnd0.txt")
read (in_file,*) vnd0
rewind(in_file)
close(in_file)

open(in_file, file = "results/guess_vd0.txt")
read (in_file,*) vd0
rewind(in_file)
close(in_file)

open(in_file, file = "results/guess_vhat0.txt")
read (in_file,*) vhat0
rewind(in_file)
close(in_file)
else
vd0 = 0.0
vnd0 = 0.0
v0 = 0.0 ! equal to max(vd0, vnd0)
vh0 = 0.0
end if

d end subroutine init_vf

!**********************************************************************
!* subroutine update_vhat
!***********************************************************************
subroutine update_vhat(n_b, n_y, Py, v0, vhat0, d_policy,&
c_policy, bn_idx_policy, pm, vhat)
implicit none

integer, intent(in) :: n_b, n_y
real(8), dimension(n_y,n_y), intent(in) :: Py
real(8), dimension(n_b,n_y,2,2), intent(in) :: v0
real(8), dimension(n_b,n_y,2,2), intent(in) :: vhat0
logical, dimension(n_b,n_y,2,2), intent(in) :: d_policy
real(8), dimension(n_b,n_y,2,2), intent(in) :: c_policy
integer, dimension(n_b,n_y,2,2), intent(in) :: &
    bn_idx_policy
type(params), intent(in) :: pm

real(8), dimension(n_b,n_y,2,2), intent(out) :: vhat

! local arrays
real(8), dimension(n_y) :: vnext

! local variables
integer :: i_t, i_h, i_y, i_b
integer :: i_t_other, i_d_other, bn_idx_other
real(8) :: c_other, u, cv_hat_val, pi_turn_other
logical :: def_other

! now, given updated policy functions, update value of !government not in power
do i_t = 1,2 ! government type
    if (i_t == 1) then
        i_t_other = 2 ! HIGH type is in power
        pi_turn_other = pm*piH/0.4
    else
        i_t_other = 1 ! LOW type is in power
        pi_turn_other = pm*piL/0.9
    end if

end do

! current history h
do i_h = 1,2
    do i_y = 1,n_y ! endowment y
do i_b = 1,n_b ! debt/assets b
    ! get consumption of other government
    c_other = c_policy(i_b,i_y,i_h,i_t_other)

! calculate utility flows to govt out of power
    u = calc_utility(c_other, pm)

! get default policy of other government
    def_other = d_policy(i_b,i_y,i_h,i_t_other)
if (def_other) then
    i_d_other = 2
else
    i_d_other = 1
end if

! get b’ policy (index) of other government
bn_idx_other = bn_idx_policy(i_b,i_y,i_h,i_t_other)

! compute continuation value
! with prob pi_turn_other, this type transitions
! into power and receives v0
! with prob 1–pi_turn_other, this type stays out
! of power and receives vhat0
vnext = pi_turn_other * v0(bn_idx_other,:,i_d_other,i_t)&
+ (1–pi_turn_other)*vhat0(bn_idx_other,:,i_d_other,i_t)
cv_hat_val = DOTPRODUCT( Py(i_y,:), vnext )

vhat(i_b,i_y,i_h,i_t) = u + pm%beta * cv_hat_val
end do
end do
end do
end subroutine update_vhat

!*********************************************************************************************************************************************
! subroutine calc_utility
!*********************************************************************************************************************************************
function calc_utility(c, pm) result(u)
implicit none

real(8), intent(in) :: c
type(params), intent(in) :: pm
real(8) :: u       ! output

if (pm%sigma == 1) then
    u = log(c)
else
u = c**(1−pm%sigma) / (1−pm%sigma)
end if

end function calc_utility

!*******************************************************************************
! subroutine calc_consumption
!*******************************************************************************
function calc_consumption(n_b, n_y, i_b, i_y, i_h, i_t, &
   i_bn, def, b_grid, y_grid, q, pm) result(c)
imPLICIT none

integer, intent(in) :: n_b, n_y, i_b, i_y, i_h, i_t, i_bn
logical :: def
real(8), dimension(n_b), intent(in) :: b_grid
real(8), dimension(n_y), intent(in) :: y_grid
real(8), dimension(n_b,n_y,2,2), intent(in) :: q

type(params), intent(in) :: pm

real(8) :: c, bn_val, b_val, tau, h_val, q_val
integer :: i_d

! default decision
if (def) then
   i_d = 2
else
   i_d = 1
end if

! get b' choice
bn_val = b_grid(i_bn)

! tax rate depends on current government type
if (i_t == 1) then
   tau = pm%tauL
else
   tau = pm%tauH
end if
! current history
if (i_h == 1) then
    h_val = 0.0
else
    h_val = 1.0
end if

! bond price
q_val = q(i_bn, i_y, i_d, i_t)  ! i_d = 1 (no default),
        ! i_d == 2 (default)

! compute consumption
c = (1 - tau) * (1 - h_val * pm%lambda) * exp(y_grid(i_y)) &
    q_val * bn_val

if (.not. def) then
    b_val = b_grid(i_b)
    c = c + b_val
end if

end function calc_consumption

!******************************************************************************
! subroutine calc_val
!******************************************************************************
function calc_val(n_b, n_y, i_b, i_y, i_h, i_t, i_bn, def, &
        b_grid, y_grid, q, cv, pm) result(val)
implicit none

integer, intent(in) :: n_b, n_y, i_b, i_y, i_h, i_t, i_bn
logical :: def
real(8), dimension(n_b), intent(in) :: b_grid
real(8), dimension(n_y), intent(in) :: y_grid
real(8), dimension(n_b, n_y, 2, 2), intent(in) :: q
real(8), dimension(n_b, n_y, 2, 2), intent(in) :: cv
type(params), intent(in) :: pm
real(8) :: val ! output
real(8) :: q_val, c, u, d_val, tau, h_val, bn_val, b_val, &
cv_val
integer :: i_d

! default decision
if (def) then
   i_d = 2
else
   i_d = 1
end if

! compute consumption
c = calc_consumption(n_b, n_y, i_b, i_y, i_h, i_t, i_bn,&
def, b_grid, y_grid, q, pm)

if (c > 0.0) then
   ! calculate utility from consumption
   u = calc_utility(c, pm)

   ! get continuation value
   cv_val = cv(i_bn, i_y, i_d, i_t)

   ! compute value of not default
   val = u + pm*b*beta * cv_val
else
   val = -huge(val)
end if

end function calc_val

!*******************************************************************************
! subroutine solve_gridsearch
!*******************************************************************************
subroutine solve_gridsearch(n_b, n_y, i_b, i_y, i_h, i_t,&
def, b_grid, y_grid, q, cv, pm, sol)
implicit none

integer, intent(in) :: n_b, n_y, i_b, i_y, i_h, i_t
logical, intent(in) :: def
real(8), dimension(n_b), intent(in) :: b_grid
real(8), dimension(n_y), intent(in) :: y_grid
real(8), dimension(n_b,n_y,2,2), intent(in) :: q
real(8), dimension(n_b,n_y,2,2), intent(in) :: cv
type(params), intent(in) :: pm
type(solution_vars), intent(out) :: sol

! local arrays
real(8), dimension(n_b) :: val_grid

! local variables
integer :: i_bn, bn_sol_idx
integer :: dbg_flag = 0
integer :: out_unit = 96

! compute val_nd, val_d for each b' on grid
do i_bn = 1, n_b
  val_grid(i_bn) = calc_val(n_b, n_y, i_b, i_y, i_h, i_t, &
                          i_bn, def, b_grid, y_grid, q, cv, pm)
end do

if (dbg_flag > 0) then
  call open_data_file(out_unit, "obj_function.txt")
  call save_array_1d(out_unit, "val", n_b, val_grid)
  call save_array_1d(out_unit, "b_grid", n_b, b_grid)
  call close_data_file(out_unit)
end if

! solve for optimal b'
bn_sol_idx = maxloc( val_grid, dim=1 )

! save solution
sol%bn_sol_idx = bn_sol_idx
sol%bn_sol = b_grid(bn_sol_idx)
sol%val = val_grid(bn_sol_idx)
sol%c_sol = calc_consumption(n_b, n_y, i_b, i_y, i_h, &
                            i_t, bn_sol_idx, def, b_grid, y_grid, q, pm)
end subroutine solve_gridsearch
! subroutine calc_bond_price_schedule

subroutine calc_bond_price_schedule(n_b, n_y, vnd0, vd0,&
    Py_cdf, pm, q, p_d, ystar)
implicit none

integer, intent(in) :: n_b, n_y
real(8), dimension(n_b,n_y,2,2), intent(in) :: vnd0
! v_nd(b,y,h,type), value of not defaulting
real(8), dimension(n_y,2,2), intent(in) :: vd0
! v_d(y,h,type), value of default
real(8), dimension(n_y,n_y), intent(in) :: Py_cdf
! Py_cdf(y,y'), cdf of probability transition matrix
type(params), intent(in) :: pm

! policy functions (output)
real(8), dimension(n_b,n_y,2,2), intent(out) :: q
! q(b',y,d,type'), q schedule
real(8), dimension(n_b,n_y,2,2), intent(out) :: p_d
! p_d(b',y,h',type'), default probability
integer, dimension(n_b,2,2), intent(out) :: ystar
! y*(b',h',type'), default thresholds

integer :: y_s
integer :: i_bn, i_hn, i tn, i_t, i_y
integer :: i_t_other
logical :: y_s_found
real(8) :: pd_val
real(8) :: pd_curr, pd_other, pi_turn, q_val

! first, compute default thresholds and default probabilities
!

do i_tn = 1,2
    ! type' (tomorrow's type)
do i_hn = 1,2
    ! h' (history tomorrow)
do i_bn = 1,n_b
    ! b' (debt tomorrow)
! Find y* such that
! country does NOT DEFAULT for y >= y*
! country does DEFAULT for y < y* (or y <= y*-1)

! if y* == 1, then country doesn’t default for any y
! if y* = n_y + 1, then country defaults fora ll y

y_s = 0
y_s_found = .false.

do while ( .not. y_s_found )
y_s = y_s + 1

! check whether country does NOT DEFAULT for this y
if ( vnd0(i_bn, y_s, i_hn, i_tn) >= &
     vd0(y_s, i_hn, i_tn) ) then
  y_s_found = .true.
else if ( y_s == n_y ) then
  ! only reach this if
  ! vnd0(b’,y’,h’,type’) < vd0(y’,h’,type’) for all y’
  y_s_found = .true.
  y_s = n_y + 1
end if

end do

! save default threshold
ystar(i_bn, i_hn, i_tn) = y_s

! compute default probabilities
do i_y = 1,n_y
  if (y_s == 1) then
    pd_val = 0d+0
  else if (y_s == n_y + 1) then
    pd_val = 1.0d+0
  else
    pd_val = Py_cdf(i_y,y_s-1)
  end if
  pd(i_bn, i_y, i_hn, i_tn) = pd_val
end do
end do ! current y loop

end do
end do
end do

! 

! second, compute bond price schedule

!

do i_t = 1,2       ! type TODAY
  do i_hn = 1,2 ! d, default decision TODAY (i.e., h')
    do i_y = 1,n_y  ! y, current y
      do i_bn = 1,n_b ! b', next period's debt choice

        ! get index for other type
        if (i_t == 1) then
          i_t_other = 2
        ! other type is the high type
          pi_turn = pm%piL/0.9! prob of turnover
        else
          i_t_other = 1
        ! other type is the low type
          pi_turn = pm%piH/0.4 ! prob of turnover
        end if

        ! current type's default probability
        pd_curr = p_d(i_bn, i_y, i_hn, i_t)

        ! other type's default probability
        pd_other = p_d(i_bn, i_y, i_hn, i_t_other)

        ! compute bond price
        q_val = 1 - pi_turn * pd_other - (1-pi_turn)*
               * pd_curr
        q_val = q_val / (1 + pm%r)

        ! save price
        q(i_bn, i_y, i_hn, i_t) = q_val
end do
end do
end do
end do

d end subroutine calc_bond_price_schedule

!********************************************************************************
! subroutine calc_cv
!********************************************************************************
subroutine calc_cv(n_b, n_y, v0, vhat0, Py, pm, cv)
implicit none

integer, intent(in) :: n_b, n_y
real(8), dimension(n_b,n_y,2,2), intent(in) :: v0
! v(b,y,h,type), value of gov’t in power
real(8), dimension(n_b,n_y,2,2), intent(in) :: vhat0
! vhat(b,y,h,type), value of gov’t out of power
real(8), dimension(n_y,n_y), intent(in) :: Py
! Py(y,y’), probability transition matrix
type(params), intent(in) :: pm

! policy functions (output)
real(8), dimension(n_b,n_y,2,2), intent(out) :: cv
! cv(b’,y,d,type), continuation values

! local array
real(8), dimension(n_y) :: vnext
real(8), dimension(2) :: pi_grid

integer :: i_bn, i_y, i_d, i_t
real(8) :: cv_val, pi_turn

pi_grid(1) = pm%piL / 0.9;
pi_grid(2) = pm%piH / 0.4;

do i_t = 1,2 ! current type, TODAY
do i_d = 1,2
! default decision, TODAY (= history tomorrow)
do i\_y = 1, n\_y  \ \! \text{output y, TODAY}
  do i\_bn = 1, n\_b  \ \! \text{b' choice}

  ! next period:
  ! with prob. pi, type i\_t will be out of power—receive vhat0
  ! with prob. 1−pi, type i\_t will still be in power—receive v0
  vnext = pi\_grid(i\_t) * vhat0(i\_bn,:,i\_d,&
  i\_t) +(1−pi\_grid(i\_t)) * v0(i\_bn,:,i\_d,i\_t)

  ! compute continuation value
  cv\_val = DOT\_PRODUCT( Py(i\_y,:), vnext )

  ! save value
  cv(i\_bn,i\_y,i\_d,i\_t) = cv\_val
.end do
.end do
.end do
.end subroutine calc\_cv

!**************************************************************************************************
! subroutine save\_vfi\_results
!**************************************************************************************************
subroutine save\_vfi\_results(n\_b, n\_y, b\_grid, y\_grid, v,&
  vnd,vd,vhat, d\_policy, c\_policy, q, bn\_policy)
implicit none

integer, intent(in) :: n\_b, n\_y
real(8), dimension(n\_b), intent(in) :: b\_grid
real(8), dimension(n\_y), intent(in) :: y\_grid
real(8), dimension(n\_b,n\_y,2,2), intent(in) :: v
real(8), dimension(n\_b,n\_y,2,2), intent(in) :: vnd
real(8), dimension(n\_y,2,2), intent(in) :: vd
real(8), dimension(n\_b,n\_y,2,2), intent(in) :: vhat
logical, dimension(n\_b,n\_y,2,2), intent(in) :: d\_policy
real(8), dimension(n\_b,n\_y,2,2), intent(in) :: c\_policy
real(8), dimension(n\_b,n\_y,2,2), intent(in) :: bn\_policy
real(8), dimension(n\_b,n\_y,2,2), intent(in) :: q
! local variables
integer :: vfi_out = 232

! save results
call open_data_file(vfi_out, "results/vfi_data.txt");

call save_array_1d(vfi_out, "b-grid", n_b, b_grid)
call save_array_1d(vfi_out, "y-grid", n_y, y_grid)
call save_array_4d(vfi_out, "v", n_b, n_y, 2, 2, v)
call save_array_4d(vfi_out, "vnd", n_b, n_y, 2, 2, vnd)
call save_array_3d(vfi_out, "vd", n_y, 2, 2, vd)
call save_array_4d(vfi_out, "vhat", n_b, n_y, 2, 2, vhat)
call save_array_4d(vfi_out, "d", n_b, n_y, 2, 2, d_policy)
call save_array_4d(vfi_out, "c", n_b, n_y, 2, 2, c_policy)
call save_array_4d(vfi_out, "q", n_b, n_y, 2, 2, q)
call save_array_4d(vfi_out, "bn", n_b, n_y, 2, 2, bn_policy)

call close_data_file(vfi_out)

! save v, vnd, vd, vhat in separate files
open (unit=vfi_out, file="results/guess_v0.txt", action=&
   "write", status="replace")
write (vfi_out,* ) v
close (vfi_out)

open (unit=vfi_out, file="results/guess_vnd0.txt", action=&
   "write", status="replace")
write (vfi_out,* ) vnd
close (vfi_out)

open (unit=vfi_out, file="results/guess_vd0.txt", action=&
   "write", status="replace")
write (vfi_out,* ) vd
close (vfi_out)

open (unit=vfi_out, file="results/guess_vhat0.txt", &
   action="write", status="replace")
write (vfi_out,*) vhat
close (vfi_out)

end subroutine save_vfi_results

end module vfi_module
Listing A.3: Simulation of Model

module sim_module
use model_tools

implicit none
contains

!********************************************************************************
! subroutine simulate
!********************************************************************************
subroutine simulate(n_b, n_y, b_grid, y_grid, Py_cdf, &
    mu_y_cdf, Pt, Pt_cdf, mu_t_cdf, q, p_d, d_policy, &
    c_policy, bn_policy, bn_idx_policy, pm)
implicit none

integer, intent(in) :: n_b, n_y
real(8), dimension(n_b), intent(in) :: b_grid
real(8), dimension(n_y), intent(in) :: y_grid
real(8), dimension(n_y,n_y), intent(in) :: Py_cdf
real(8), dimension(n_y), intent(in) :: mu_y_cdf
real(8), dimension(2,2), intent(in) :: Pt
real(8), dimension(2,2), intent(in) :: Pt_cdf
real(8), dimension(2), intent(in) :: mu_t_cdf
real(8), dimension(n_b,n_y,2,2), intent(in) :: q
real(8), dimension(n_b,n_y,2,2), intent(in) :: p_d
logical, dimension(n_b,n_y,2,2), intent(in) :: d_policy
real(8), dimension(n_b,n_y,2,2), intent(in) :: c_policy
real(8), dimension(n_b,n_y,2,2), intent(in) :: bn_policy
integer, dimension(n_b,n_y,2,2), intent(in) :: bn_idx_policy
type(params), intent(in) :: pm

! local arrays (make allocatable to avoid memory problems)
integer, allocatable, dimension(:, :) :: sim_type
! simulated type ( = 1, low type, = 2, high type )
integer, allocatable, dimension(:, :) :: sim_y
! this is just the index for output
real(8), allocatable, dimension(:, :) :: sim_output
! this is actual simulated output
real(8), allocatable, dimension(:,:) :: sim_b
! simulated b'
integer, allocatable, dimension(:,:) :: sim_b_idx
! simulated b' choice (index)
integer, allocatable, dimension(:,:) :: sim_h
! simulated history (=1 if no default prev period, ..
!=2 if default)
logical, allocatable, dimension(:,:) :: sim_d
! simulated default decision
real(8), allocatable, dimension(:,:) :: sim_c
! simulated consumption
real(8), allocatable, dimension(:,:) :: sim_bn
! simulated b' choice
integer, allocatable, dimension(:,:) :: sim_bn_idx
! simulated b' choice (index)
real(8), allocatable, dimension(:,:) :: sim_pd
! simulated default probability
real(8), allocatable, dimension(:,:) :: sim_q
! simulated bond price

integer :: n_samples, n_periods
integer :: i, t
integer :: i_b, i_y, i_h, i_t ! current state
integer :: i_bn, i_d ! current choices
logical :: def
integer :: sim_out = 123

n_samples = pm%n_samples! number of samples in simulation
n_periods = pm%n_periods
! number of periods for each sample in simulation

! allocate memory
allocate ( sim_type(n_periods, n_samples), sim_y(n_periods,&
           n_samples), sim_output(n_periods, n_samples) )
allocate ( sim_b(n_periods, n_samples), sim_b_idx(n_periods,&
           n_samples), sim_h(n_periods, n_samples) )
allocate ( sim_d(n_periods, n_samples), sim_c(n_periods, &
n_samples), sim_bn(n_periods, n_samples) )
allocate ( sim_bn_idx(n_periods, n_samples), sim_q(n_periods,&
n_samples), sim_pd(n_periods, n_samples) )

do i = 1, n_samples

! simulate types (all at once) for this sample
call gen_shocks( n_periods, 2, mu_t_cdf, Pt_cdf,&
sim_type(:,i) )

! simulate y (all at once) for this sample
call gen_shocks( n_periods, n_y, mu_y_cdf, Py_cdf,&
sim_y(:,i) )

! initialize policy choices
i_bn = n_b ! max b'
i_d = 1 ! no default

do t = 1, n_periods
  ! update initial state from choices last period
  i_b = i_bn
  i_h = i_d

  ! update initial state for output and type
  i_t = sim_type(t,i)
i_y = sim_y(t,i)

  ! save state
  sim_h(t,i) = i_h
  sim_b_idx(t,i) = i_b
  sim_b(t,i) = b_grid(i_b)
sim_output(t,i) = exp( y_grid(i_y) )

  ! policy choices
  i_bn = bn_idx_policy( i_b, i_y, i_h, i_t )
  def = d_policy( i_b, i_y, i_h, i_t )
  if (def) then
    i_d = 2
  else

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\begin{verbatim}

i_d = 1
end if

! save policy choices
sim_d(t,i) = def
sim_c(t,i) = c_policy( i_b, i_y, i_h, i_t )
sim_bn(t,i) = bn_policy( i_b, i_y, i_h, i_t )
sim_bn_idx(t,i) = i_bn

! bond price, given policy choices
sim_q(t,i) = q( i_bn, i_y, i_d, i_t )

! default probability, given policy choices
! p_d gives the probability of default, given the
! type in gov't tomorrow
sim_pd(t,i) = DOT_PRODUCT( Pt(t,:), p_d( i_bn,&
i_y, i_d, :) )

end do

if (mod(i, 10) == 1) then
    print *, "sample = ", i
end if
end do

! save simulation results
print*, "******************************
print*, "Saving Simulation Results"
print*, "******************************

call open_data_file(sim_out, "results/sim_data.txt");
call save_array_2d(sim_out, "sim_type", n_periods, &
n_samples, sim_type)
call save_array_2d(sim_out, "sim_output", n_periods,&

\end{verbatim}
n_samples, sim_output)
call save_array_2d(sim_out, "sim_b", n_periods, n_samples,
    sim_b)
call save_array_2d(sim_out, "sim_bn", n_periods, n_samples,
    sim_bn)
call save_array_2d(sim_out, "sim_q", n_periods, n_samples,
    sim_q)
call save_array_2d(sim_out, "sim_pd", n_periods, n_samples,
    sim_pd)
call save_array_2d(sim_out, "sim_d", n_periods, n_samples,
    sim_d)
call save_array_2d(sim_out, "sim_c", n_periods, n_samples,
    sim_c)
call close_data_file(sim_out)
end subroutine simulate

!*****************************************************************************
! subroutine gen_shocks
!*****************************************************************************
subroutine gen_shocks(n_periods, num_shocks, mu_cdf, &
    P_cdf, sim_shock)
integer, intent(in) :: n_periods, num_shocks
real(8), dimension(num_shocks), intent(in) :: mu_cdf
real(8), dimension(num_shocks,num_shocks), intent(in) :: &
    P_cdf
integer, dimension(n_periods), intent(out) :: sim_shock
real(8), allocatable, dimension(:) :: u
integer :: t

! allocate memory for u
allocate (u(n_periods))

! generate random variables, which is uniformly
! distributed [0,1)
call RANDOMNUMBER(u)
! first calculate initial type
sim_shock(1) = calc_markov_shock_from_uniform_rv(u(1), &
           num_shocks, mu_cdf)

! now determine types for all future periods
do t = 2, n_periods
   sim_shock(t) = calc_markov_shock_from_uniform_rv( &
               u(t), num_shocks, P_cdf(sim_shock(t-1),:))
end do

dallocate (u)
end subroutine gen_shocks

!***********************************************************
! function calc_markov_shock_from_uniform_rv
!***********************************************************
function calc_markov_shock_from_uniform_rv(u, n, P_cdf)&
   result(j)
implicit none

real(8), intent(in) :: u
integer, intent(in) :: n
real(8), dimension(n), intent(in) :: P_cdf
integer :: j  ! output

! local variables
logical :: done

done = .false.
j = 0

! u is uniformly distributed over [0,1)
! convert it into an index for productivity
! using the cumulative probability transition matrix
do while ( .not. done )
   j = j + 1;
   
   ! stop if u < P_cdf(j)
! u has to be less than 1
! P_{cdf}(n) == 1, so eventually this will be true
     done = (u < P_{cdf}(j));
end do

d function calc_markov_shock_from_uniform_rv

end module sim_module
Listing A.4: Main Program: Driver for Iteration and Simulation

program corruption_model
use model_tools
use grid_module
use vfi_module
use sim_module

implicit none

! Variables
type(params) :: pm
real(8), allocatable, dimension(:) :: b_grid
! b grid points
real(8), allocatable, dimension(:) :: y_grid
! y grid points
real(8), allocatable, dimension(:,:) :: Py
! prob transition matrix for y
real(8), allocatable, dimension(:,:) :: Py_cdf
! prob transition matrix for y, cdf
real(8), allocatable, dimension(:) :: mu_y
! inv distribution for y
real(8), allocatable, dimension(:) :: mu_y_cdf
! inv distribution for y, cdf
real(8), allocatable, dimension(:,:) :: Pt
! prob transition matrix, government type
real(8), allocatable, dimension(:,:) :: Pt_cdf
! prob transition matrix, government type, cdf
real(8), allocatable, dimension(:) :: mu_t
! inv distribution for government type
real(8), allocatable, dimension(:) :: mu_t_cdf
! inv distribution for government type, cdf

real(8), allocatable, dimension(:,:,:,:) :: q
! q(b',y,d,type), q schedule
real(8), allocatable, dimension(:,:,:,:) :: p_d
! p_d(b',y,h',type'), default probability
integer, allocatable, dimension(:,:,:,:) :: ystar
! y*(b',h',type'), default thresholds
logical, allocatable, dimension(:,:,:,:) :: d_policy
! d(b,y,hist,type'), default policy
real(8), allocatable, dimension(:,:,:,:) :: c_policy
! c(b,y,hist,type'), consumption policy
real(8), allocatable, dimension(:,:,:,:) :: bn_policy
! b'(b,y,hist,type'), debt policy
integer, allocatable, dimension(:,:,:,:) :: bn_idx_policy
! b'(b,y,hist,type'), debt policy (index)

integer :: n_b, n_y

%%%%% Load parameters

! load parameters
call load_parameters("input_params.txt", pm)
n_b = pm%n_b
n_y = pm%n_y

! save parameters into a format that will be easier...
! to read in Matlab
call save_parameters(pm)

%%%%% Allocate memory
! to avoid memory problems, arrays made allocatable...
! and memory explicitly allocated
allocate ( b_grid(n_b), y_grid(n_y) )
allocate ( Py(n_y,n_y), Py_cdf(n_y,n_y), mu_y(n_y),&
        mu_y_cdf(n_y) )
allocate ( Pt(2,2), Pt_cdf(2,2), mu_t(2), mu_t_cdf(2) )
allocate ( q(n_b,n_y,2,2), p_d(n_b,n_y,2,2), d_policy&
        (n_b,&n_y,2,2), c_policy(n_b,n_y,2,2) )
allocate ( bn_policy(n_b,n_y,2,2), bn_idx_policy(n_b,&
        n_y,2,2) )
allocate ( ystar(n_b,2,2) )

%%%%% Construct grids
call construct_grids(pm, b_grid, y_grid, Py, Py_cdf, &
                 mu_y, mu_y_cdf, Pt, Pt_cdf, mu_t, mu_t_cdf)

print*, "**************************************************"
prompt*, "Value Function Iteration"
prompt*, "**************************************************" 

%%%%%% Value Function Iteration
call val_fcn_iter(n_b, n_y, b_grid, y_grid, Py, Py_cdf,&
                 pm, q, p_d, ystar, d_policy, c_policy, bn_policy, &
                 bn_idx_policy)

print*, "**************************************************"
prompt*, "Simulation"
prompt*, "**************************************************"

%%%%%% Simulation
call simulate(n_b, n_y, b_grid, y_grid, Py_cdf,&
              mu_y_cdf, Pt, Pt_cdf, mu_t_cdf, q, p_d, d_policy,&
              c_policy, bn_policy, bn_idx_policy, pm)

print*, "**************************************************"
prompt*, "Program Done"
prompt*, "**************************************************" 

end program corruption_model
module grid_module
use model_tools
use array_tools

implicit none

contains

! subroutine construct_grids
 subroutine construct_grids(pm, b_grid, y_grid, Py, &
Py_cdf, mu_y, mu_y_cdf, Pt, Pt_cdf, mu_t, mu_t_cdf)
 implicit none

type(params), intent(in) :: pm
real(8), dimension(pm%n_b), intent(out) :: b_grid
real(8), dimension(pm%n_y), intent(out) :: y_grid
real(8), dimension(pm%n_y,pm%n_y), intent(out) :: Py
real(8), dimension(pm%n_y,pm%n_y), intent(out) :: Py_cdf
real(8), dimension(pm%n_y), intent(out) :: mu_y
real(8), dimension(pm%n_y), intent(out) :: mu_y_cdf
real(8), dimension(2,2), intent(out) :: Pt
real(8), dimension(2,2), intent(out) :: Pt_cdf
real(8), dimension(2), intent(out) :: mu_t
real(8), dimension(2), intent(out) :: mu_t_cdf

! local arrays
real(8), dimension(pm%n_y-1) :: y_mid

! local variables
integer :: n_b, n_y
integer :: i, j
real(8) :: y_mean

! need to declare alnorm function (contained in asa066.f90)
 real(8) :: alnorm ! calculates normal cdf
get number of grid dpoints
n_b = pm%n_b
n_y = pm%n_y

! construct grid points for assets
! call expspace(n_b, pm%b_scale, pm%b_min, pm%b_max, b_grid)

! construct grid points for endowment, y
! call linspace(n_y, pm%y_min, pm%y_max, y_grid);

! construct tauchen approximation for endowment process
! construct midpoint of grid points
do i = 1, n_y-1
    y_mid(i) = 0.5*(y_grid(i) + y_grid(i+1))
end do

! construct Tauchen approximation for probability transition matrix
! mean of endowment process
y_mean = (1-pm%rho)*pm%mean_y + pm%rho * y_grid(i)

! using false input, alnorm returns normal cdf
Py(i,1) = alnorm( (y_mid(1) - y_mean) / pm%sigma_e &
                 , .false. );

! using true input, alnorm returns 1 - cdf
\[ Py(i, n_y) = \text{alnorm} \left( \frac{y_{\text{mid}(n_y-1)} - y_{\text{mean}}}{\text{pm} \% \sigma_e}, \text{.true.} \right); \]

! compute probabilities for remaining grid points
\[
do j = 2, n_y - 1
\quad Py(i, j) = \text{alnorm} \left( \frac{y_{\text{mid}(j)} - y_{\text{mean}}}{\text{pm} \% \sigma_e}, \text{.false.} \right) - \text{alnorm} \left( \frac{y_{\text{mid}(j-1)} - y_{\text{mean}}}{\text{pm} \% \sigma_e}, \text{.false.} \right)
\end do
\]

end do

! construct cdf for probability transition matrix
\[
Py_{\text{cdf}} = \text{cumsum}(Py, \text{dim}=2)
\]

! construct invariant distribution for \( y \)
\[
call \text{calc_inv_dist}(n_y, Py, mu_y, mu_y_{\text{cdf}})
\]

! construct probability transition matrix for the type of government
\[
\text{construct probability transition matrix}
\]
\[
Pt(1,1) = 1 - \text{pm} \% \text{piL} / 0.9; \quad Pt(1,2) = \text{pm} \% \text{piL} / 0.9;
\]
\[
Pt(2,1) = \text{pm} \% \text{piH} / 0.4; \quad Pt(2,2) = 1 - \text{pm} \% \text{piH} / 0.4;
\]

! construct cdf for prob transition matrix
\[
Pt_{\text{cdf}} = \text{cumsum}(Pt, \text{dim}=2)
\]

! construct invariant distribution for government types
\[
call \text{calc_inv_dist}(2, Pt, mu_t, mu_t_{\text{cdf}})
\]

end subroutine construct_grids
subroutine calc_inv_dist

! Compute invariant distribution of z' by iterating on...
! probability
! transition matrix until convergence.
! Could alternatively calculate this by computing the...
! eigenvectors
! of the probability transition matrix.

subroutine calc_inv_dist(n, P, mu, mu_cdf)

integer, intent(in) :: n        ! number of grid points
real(8), dimension(n,n), intent(in) :: P
! transition matrix
real(8), dimension(n), intent(out) :: mu
! invariant distribution
real(8), dimension(n), intent(out) :: mu_cdf
! cdf of invariant distribution

real(8), parameter :: TOL = 1.0e-12
integer, parameter :: MAX_ITER = 1000
real(8) :: err
integer :: j, iter
logical :: done

! local array
real(8), dimension(n) :: mu0

! solve for invariant distribution by iterating
! until it converges
mu0 = 1.0
iter = 0;
done = .false.

do while ( .not. done )
    ! compute next period's distribution
    mu = matmul ( transpose(P), mu0 );

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! compute convergence error
err = maxval( abs( (mu - mu0) / mu0 ), dim=1 )

! stop if error has sufficiently converged
if ( err < TOL) then
    done = .true.
end if

! stop if maximum iterations reached
iter = iter + 1;
if ( iter >= MAX_ITER) then
    done = .true.
end if

! update initial distribution
mu0 = mu;
end do

! normalize distribution
mu = mu / sum(mu)

! Now compute cdf
mu_cdf = cumsum(mu)

end subroutine calc_inv_dist
end module grid_module
Listing A.6: Model Tools

module model_tools
use data_output

implicit none

! Define structure to hold parameters
type params

  integer :: n_b
  ! number of debt grid points
  integer :: n_y
  ! number of output grid points
  integer :: n_samples
  ! number of samples in simulation
  integer :: n_periods
  ! number of periods for each sample in simulation

  real(8) :: beta       ! discount factor
  real(8) :: sigma      ! risk aversion
  real(8) :: r          ! risk free rate
  real(8) :: rho        ! persistence of output
  real(8) :: sigma_e    ! std dev of innovation to output
  real(8) :: lambda     ! output loss in default
  real(8) :: tauL       ! less corrupt type, tax
  real(8) :: tauH       ! more corrupt type, tax
  real(8) :: piL        ! probability of turnover, less corrupt type
  real(8) :: piH        ! probability of turnover, more corrupt type

  real(8) :: b_min      ! minimum asset level
  real(8) :: b_max      ! maximum asset level
  real(8) :: b_scale    ! controls interval between asset grid points
  real(8) :: y_width    ! ln y in [ mean − width * sd_y , mean + width *sd_y ]
logical :: new_v0

! if = 1, initialize val fcns to 0, otherwise...
! load from files

! derived parameters
real(8) :: mean_y ! mean of y
real(8) :: sd_y ! standard deviation of y
real(8) :: y_min
real(8) :: y_max

end type params

contains

!*****************************************************************************
! subroutine load_parameters
!*****************************************************************************
subroutine load_parameters(filename, pm)
implicit none

character(len=*), intent(in) :: filename

type(params), intent(out) :: pm

! local variables
integer:: in_file, new_v0_int

in_file = 54

open(in_file, file = filename)
read(in_file,*) pm%n_b
read(in_file,*) pm%n_y
read(in_file,*) pm%n_samples
read(in_file,*) pm%n_periods
read(in_file,*) pm%beta
read(in_file,*) pm%sigma
read(in_file,*) pm%r
read(in_file,*) pm%rho
read(in_file,*) pm%sigma_e
read(in_file,*) pm%lambda
read(in_file,*) pm%tauL
read(in_file,*) pm%tauH
read(in_file,*) pm%piL
read(in_file,*) pm%piH
read(in_file,*) pm%b_min
read(in_file,*) pm%b_max
read(in_file,*) pm%b_scale
read(in_file,*) pm%y_width
read(in_file,*) new_v0_int
rewind(in_file)
close(in_file)

! derived parameters
pm%sd_y = pm%sigma_e / sqrt( 1 - pm%rho**2 )

! mean of y:
! y' = (1-rho)*mean_y + rho* y + eps
pm%mean_y = - 0.5 * pm%sigma_e**2

! limits for endowment grid
pm%y_min = pm%mean_y - pm%y_width * pm%sd_y
pm%y_max = pm%mean_y + pm%y_width * pm%sd_y

if ( new_v0_int > 0) then
  pm%new_v0 = .true.
else
  pm%new_v0 = .false.
end if

end subroutine load_parameters

!******************************************************************************
! subroutine save_parameters
!******************************************************************************
subroutine save_parameters(pm)
implicit none
type(params), intent(in) :: pm

! local variables
integer :: param_out = 37

! save parameters

call open_data_file(param_out, "results/params.txt");

call save_scalar(param_out, "n_b", pm%n_b)
call save_scalar(param_out, "n_y", pm%n_y)
call save_scalar(param_out, "n_samples", pm%n_samples)
call save_scalar(param_out, "n_periods", pm%n_periods)
call save_scalar(param_out, "beta", pm%beta)
call save_scalar(param_out, "sigma", pm%sigma)
call save_scalar(param_out, "r", pm%r)
call save_scalar(param_out, "rho", pm%rho)
call save_scalar(param_out, "sigma_e", pm%sigma_e)
call save_scalar(param_out, "lambda", pm%lambda)
call save_scalar(param_out, "tauL", pm%tauL)
call save_scalar(param_out, "tauH", pm%tauH)
call save_scalar(param_out, "piL", pm%piL)
call save_scalar(param_out, "piH", pm%piH)
call save_scalar(param_out, "b_min", pm%b_min)
call save_scalar(param_out, "b_max", pm%b_max)
call save_scalar(param_out, "y_width", pm%y_width)
call save_scalar(param_out, "mean_y", pm%mean_y)
call save_scalar(param_out, "sd_y", pm%sd_y)
call save_scalar(param_out, "y_min", pm%y_min)
call save_scalar(param_out, "y_max", pm%y_max)

call close_data_file(param_out)

end subroutine

dend module model_tools
Listing A.7: Data Output

module data_output

implicit none

interface save_scalar
module procedure save_scalar_double, save_scalar_int,&
    save_scalar_logical
end interface

interface save_array_1d
module procedure save_array_1d_double, &
    save_array_1d_int, save_array_1d_logical
end interface

interface save_array_2d
module procedure save_array_2d_double, &
    save_array_2d_int, save_array_2d_logical
end interface

interface save_array_3d
module procedure save_array_3d_double, save_array_3d_int,&
    save_array_3d_logical
end interface

interface save_array_4d
module procedure save_array_4d_double, save_array_4d_int,&
    save_array_4d_logical
end interface

contains

!*****************************************************************************
! subroutine open_data_file
!*****************************************************************************
! choose any integer for out_unit > 0, except 6?
subroutine open_data_file(out_unit, filename)
integer, intent(in) :: out_unit
character(len=*)  , intent(in) :: filename

open ( unit=out_unit , file=filename , action="write" , status=&
"replace")
end subroutine open_data_file

!***************************************************************************
! subroutine close_data_file
!***************************************************************************
subroutine close_data_file(out_unit)
implicit none

integer, intent(in) :: out_unit

close ( out_unit )
end subroutine close_data_file

!***************************************************************************
! subroutine save_scalar_double
!***************************************************************************
implicit none

integer, intent(in) :: out_unit
character(len=*) , intent(in) :: name
real(8) , intent(in) :: val

! record details of variable
! name, # of dimensions , 1 x 1 array (i.e., scalar)
write (out_unit,*) name, " 2 1 1"

! save value to file
write (out_unit,*) val

! add an extra space
write (out_unit,*) ""
end subroutine save_scalar_double

!*****************************************************************************
! subroutine save_scalar_int
!*****************************************************************************
subroutine save_scalar_int(out_unit, name, val)
implicit none

integer, intent(in) :: out_unit
character(len=*) , intent(in) :: name
integer, intent(in) :: val

! record details of variable
! name, # of dimensions, 1 x 1 array (i.e., scalar)
write (out_unit,*) name, " 2 1 1"

! save value to file
write (out_unit,*) val

! add an extra space
write (out_unit,*) ""

end subroutine save_scalar_int

!*****************************************************************************
! subroutine save_scalar_logical
!*****************************************************************************
subroutine save_scalar_logical(out_unit, name, val)
implicit none

integer, intent(in) :: out_unit
character(len=*) , intent(in) :: name
logical , intent(in) :: val
integer :: val_out

! convert value to integer
if (val) then
    val_out = 1
else
val_out = 0
end if

! record details of variable
! name, # of dimensions, 1 x 1 array (i.e., scalar)
write (out_unit,*) name, " 2 1 1"

! save value to file
write (out_unit,*) val_out

! add an extra space
write (out_unit,*) ""
end subroutine save_scalar_logical

!*************************************************************************
! subroutine save_array_1d_double
!*************************************************************************
subroutine save_array_1d_double(out_unit, name, n, vals)
imPLICIT none

INTEGER, INTENT(IN) :: out_unit
CHARACTER(Len=*) , INTENT(IN) :: name
INTEGER, INTENT(IN) :: n
REAL(8) , DIMENSION(n), INTENT(IN) :: vals

! record details of variable
! name, # of dimensions, n x 1 vector
write (out_unit,*) name, " 2 ", n, " 1"

! save array to file
write (out_unit,*) vals

! add an extra space
write (out_unit,*) ""
end subroutine save_array_1d_double

!*************************************************************************
! subroutine save_array_1d_int
!**********************************************************************
subroutine save_array_1d_int(out_unit, name, n, vals)
implicit none

integer, intent(in) :: out_unit
character(len=1), intent(in) :: name
integer, intent(in) :: n
integer, dimension(n), intent(in) :: vals

! record details of variable
! name, # of dimensions, n x 1 vector
write (out_unit,*), name, " 2 " , n, " 1"

! save array to file
write (out_unit,*), vals

! add an extra space
write (out_unit,*), " 

end subroutine save_array_1d_int

!**********************************************************************
! subroutine save_array_1d_logical
!**********************************************************************
subroutine save_array_1d_logical(out_unit, name, n, vals)
implicit none

integer, intent(in) :: out_unit
character(len=1), intent(in) :: name
integer, intent(in) :: n
logical, dimension(n), intent(in) :: vals

integer, allocatable, dimension(:) :: vals_out
integer :: i

allocate (vals_out(n))

! convert to integers
! where construct can cause stack overflow?!
! where ( vals )
! vals_out = 1
! elsewhere
! vals_out = 0
! end where

doi = 1,n
if ( vals(i) ) then
  vals_out(i) = 1
else
  vals_out(i) = 0
end if
end do

! record details of variable
! name, # of dimensions, n x 1 vector
write ( outunit,*) name, " 2 " , n, " 1"

! save array to file
write ( outunit,*) vals_out

! add an extra space
write ( outunit,*) ""
deallocate ( vals_out )
end subroutine save_array_1d_logical

*****************************************************************************
! subroutine save_array_2d_double
*****************************************************************************
subroutine save_array_2d_double(out_unit, name, n1, n2,&
  vals)
imPLICIT none

INTEGER, INTENT(IN) :: out_unit
CHARACTER(len=*) , INTENT(IN) :: name
INTEGER , INTENT(IN) :: n1
integer, intent(in) :: n2
real(8), dimension(n1,n2), intent(in) :: vals

! record details of variable
! name, # of dimensions, n1 x n2 array
write (out_unit,* ) name, " 2 ", n1, n2

! save array to file
write (out_unit,* ) vals

! add an extra space
write (out_unit,* ) ""
end subroutine save_array_2d_double

*****************************************************************************
! subroutine save_array_2d_int
*****************************************************************************
subroutine save_array_2d_int(out_unit, name, n1, n2,&
   vals)
implicit none

integer, intent(in) :: out_unit
character(len=*/, intent(in) :: name
integer, intent(in) :: n1
integer, intent(in) :: n2
integer, dimension(n1,n2), intent(in) :: vals

! record details of variable
! name, # of dimensions, n1 x n2 array
write (out_unit,* ) name, " 2 ", n1, n2

! save array to file
write (out_unit,* ) vals

! add an extra space
write (out_unit,* ) ""
end subroutine save_array_2d_int
subroutine save_array_2d_logical(out_unit, name, n1, & n2, vals)
    implicit none

    integer, intent(in) :: out_unit
    character(len=*) , intent(in) :: name
    integer, intent(in) :: n1
    integer, intent(in) :: n2
    logical, dimension(n1,n2) , intent(in) :: vals

    integer, allocatable , dimension(:, :) :: vals_out
    integer :: i1, i2

    allocate (vals_out(n1,n2))

    ! convert to integers
    ! where construct causing stack overflow?!
    ! where ( vals )
    ! vals_out = 1
    ! elsewhere
    ! vals_out = 0
    ! end where

    do i2 = 1,n2
        do i1 = 1,n1
            if (vals(i1,i2)) then
                vals_out(i1,i2) = 1
            else
                vals_out(i1,i2) = 0
            end if
        end do
    end do

    ! record details of variable
    ! name, # of dimensions, n1 x n2 array
write (out_unit,*) name, " 2 ", n1, n2

! save array to file
write (out_unit,*) vals_out

! add an extra space
write (out_unit,*) ""
dereference (vals_out)
end subroutine save_array_2d_logical

!******************************************************************************
! subroutine save_array_3d_double
!******************************************************************************
subroutine save_array_3d_double(out_unit, name, n1, n2,&
    n3, vals)
implicit none

integer, intent(in) :: out_unit
character(len=*) , intent(in) :: name
integer, intent(in) :: n1
integer, intent(in) :: n2
integer, intent(in) :: n3
real(8), dimension(n1,n2,n3), intent(in) :: vals

! record details of variable
! name, # of dimensions, n1 x n2 x n3 array
write (out_unit,*) name, " 3 ", n1, n2, n3

! save array to file
write (out_unit,*) vals

! add an extra space
write (out_unit,*) ""
end subroutine save_array_3d_double

!******************************************************************************
! subroutine save_array_3d_int

subroutine save_array_3d_int (out_unit, name, n1, n2, &
n3, vals)

implicit none

integer, intent(in) :: out_unit
character(len=*)    , intent(in) :: name
integer             , intent(in) :: n1
integer             , intent(in) :: n2
integer             , intent(in) :: n3
integer, dimension(n1,n2,n3), intent(in) :: vals

! record details of variable
! name, # of dimensions, n1 x n2 x n3 array
write (out_unit,*) name, " 3 ", n1, n2, n3

! save array to file
write (out_unit,*) vals

! add an extra space
write (out_unit,*) ""

end subroutine save_array_3d_int

! subroutine save_array_3d_logical

subroutine save_array_3d_logical (out_unit, name, n1, n2, &
n3, vals)

implicit none

integer, intent(in) :: out_unit
character(len=*)    , intent(in) :: name
integer             , intent(in) :: n1
integer             , intent(in) :: n2
integer             , intent(in) :: n3
logical, dimension(n1,n2,n3), intent(in) :: vals
integer, allocatable, dimension(:,:,:,:) :: vals_out
integer :: i1,i2,i3

allocate (vals_out(n1,n2,n3))

! convert to integers
! where construct causing stack overflow?!
!where ( vals )
! vals_out = 1
!elsewhere
! vals_out = 0
!end where

doi3 = 1,n3
do i2 = 1,n2
do i1 = 1,n1
  if (vals(i1,i2,i3)) then
    vals_out(i1,i2,i3) = 1
  else
    vals_out(i1,i2,i3) = 0
  end if
end do
end do
doi3 = 1,n3
do i2 = 1,n2
do i1 = 1,n1
  if (vals(i1,i2,i3)) then
    vals_out(i1,i2,i3) = 1
  else
    vals_out(i1,i2,i3) = 0
  end if
end do
end do

! record details of variable
! name, # of dimensions, n1 x n2 x n3 array
write (out_unit,*) name, " 3 ", n1, n2, n3

! save array to file
write (out_unit,*) vals_out

! add an extra space
write (out_unit,*) ""
dallocate (vals_out)
end subroutine save_array_3d_logical
** SUBROUTINE SAVE_ARRAY_4D_DOUBLE **

** SUBROUTINE SAVE_ARRAY_4D_DOUBLE (OUT_UNIT, NAME, N1, N2,&**

** N3, N4, VALS) **

** IMPLICIT NONE **

INTEGER, INTENT(IN) :: OUT_UNIT
CHARACTER(len=*) INTENT(IN) :: NAME
INTEGER, INTENT(IN) :: N1
INTEGER, INTENT(IN) :: N2
INTEGER, INTENT(IN) :: N3
INTEGER, INTENT(IN) :: N4
REAL(8), DIMENSION(N1,N2,N3,N4), INTENT(IN) :: VALS

** ! RECORD DETAILS OF VARIABLE **
** ! NAME, # OF DIMENSIONS, N1 X N2 X N3 X N4 ARRAY **
WRITE (OUT_UNIT,*)(NAME, " 4 ", N1, N2, N3, N4)

** ! SAVE ARRAY TO FILE **
WRITE (OUT_UNIT,*)(VALS)

** ! ADD AN EXTRA SPACE **
WRITE (OUT_UNIT,*)("")

eND SUBROUTINE SAVE_ARRAY_4D_DOUBLE

** SUBROUTINE SAVE_ARRAY_4D_INT **

** SUBROUTINE SAVE_ARRAY_4D_INT (OUT_UNIT, NAME, N1, N2,&**

** N3, N4, VALS) **

** IMPLICIT NONE **

INTEGER, INTENT(IN) :: OUT_UNIT
CHARACTER(len=*) INTENT(IN) :: NAME
INTEGER, INTENT(IN) :: N1
INTEGER, INTENT(IN) :: N2
INTEGER, INTENT(IN) :: N3
integer, intent(in) :: n4
integer, dimension(n1,n2,n3,n4), intent(in) :: vals

! record details of variable
! name, # of dimensions, n1 x n2 x n3 x n4 array
write (out_unit,*), name, " 4 ", n1, n2, n3, n4

! save array to file
write (out_unit,*), vals

! add an extra space
write (out_unit,*), ""

end subroutine save_array_4d_int

*****************************************************************************
!* subroutine save_array_4d_logical
*****************************************************************************
subroutine save_array_4d_logical(out_unit, name, n1, n2,&
     n3, n4, vals)
implicit none

integer, intent(in) :: out_unit
character(len=1), intent(in) :: name
integer, intent(in) :: n1
integer, intent(in) :: n2
integer, intent(in) :: n3
integer, intent(in) :: n4
logical, dimension(n1,n2,n3,n4), intent(in) :: vals

integer, allocatable, dimension(:,:,:) :: vals_out
integer :: i1,i2,i3,i4
allocate (vals_out(n1,n2,n3,n4))

! convert to integers
! where construct causing stack overflow?
!where ( vals )
! vals_out = 1
! elsewhere
!     vals_out = 0
! end where

    do i4 = 1,n4
        do i3 = 1,n3
            do i2 = 1,n2
                do i1 = 1,n1
                    if (vals(i1,i2,i3,i4)) then
                        vals_out(i1,i2,i3,i4) = 1
                    else
                        vals_out(i1,i2,i3,i4) = 0
                    end if
                end do
            end do
        end do
    end do

! record details of variable
! name, # of dimensions, n1 x n2 x n3 x n4 array
write (out_unit,*) name, " 4 ", n1, n2, n3, n4

! save array to file
write (out_unit,*) vals_out

! add an extra space
write (out_unit,*) ""
deallocate (vals_out)

end subroutine save_array_4d_logical

end module data_output
Listing A.8: Array Tools

module array_tools

implicit none

interface cumsum
module procedure cumsum_matrix, cumsum_vector
end interface

contains

!**********************************************************************!
! subroutine expspace
!**********************************************************************!
subroutine expspace(n_x, x_scale, x_min, x_max, x_vec)
implicit none

integer, intent(in) :: n_x
real(8), intent(in) :: x_scale, x_min, x_max
real(8), dimension(n_x), intent(out) :: x_vec

integer :: i
real(8) :: step

!---!--
! construct grid points
step = (x_max - x_min)/ real(n_x-1, kind=8)**x_scale
do i=1,n_x-1
   x_vec(i) = x_min + step*(i-1)**x_scale;
end do
x_vec(n_x) = x_max

end subroutine expspace

!**********************************************************************!
! subroutine linspace
!**********************************************************************!

subroutine linspace(n_x, x_min, x_max, x_vec)
implicit none

integer, intent(in) :: n_x
real(8), intent(in) :: x_min, x_max
real(8), dimension(n_x), intent(out) :: x_vec

integer :: i
real(8) :: step

!----!
! construct grid points
step = (x_max - x_min)/(n_x-1)
do i=1,n_x
   x_vec(i) = x_min + step*(i-1);
end do
end subroutine linspace

********************************************************************
! subroutine cumsum_matrix
********************************************************************
! Cumsum computes the cumulative sum.
!
! After calling B = cumsum(A, DIM=1)
! B will contain the cumulative sum of A along each column
! After calling B = cumsum(A, DIM=2)
! B will contain the cumulative sum of A along each row
function cumsum_matrix(A, dim) result(B)
implicit none

real(8), dimension(,:,:), intent(in) :: A
integer, intent(in) :: dim
real(8), dimension(size(A,dim=1),size(A,dim=2)) :: B

integer :: i, j
integer :: M, N
real(8) :: sum_val
! get dimensions of A
M = size(A, dim=1)  ! number of rows
N = size(A, dim=2)  ! number of column

if (dim == 1) then
! sum across dimension 1 (columns)
    do j = 1,N
        ! initialize cumulative sum
        sum_val = 0.0;

        ! loop across each row of C
        do i = 1,M
            sum_val = sum_val + A(i,j);
            B(i,j) = sum_val;
        end do
    end do
else if (dim == 2) then
! sum across dimension 2 (rows)
    ! loop across each row of C
    do i = 1,M
        ! initialize cumulative sum
        sum_val = 0.0;

        ! loop across each column of C
        do j = 1,N
            sum_val = sum_val + A(i,j);
            B(i,j) = sum_val;
        end do
    end do
else
    ! error
end if

end function cumsum_matrix

!**************************************************************************************
subroutine cumsum_vector
!**********************************************************************
! Cumsum computes the cumulative sum.
!
! After calling B = cumsum(A)
! B will contain the cumulative sum of A
function cumsum_vector(A) result(B)
implicit none
real(8), dimension(:), intent(in) :: A
real(8), dimension(size(A)) :: B
integer :: i, N

! get dimensions of A
N = size(A) ! number of elements in A

! calculate cumulative sum
if (N > 0) then
  B(1) = A(1)
  do i = 2,N
    B(i) = B(i-1) + A(i)
  end do
end if
end function cumsum_vector

******************************************************************************
subroutine sort
******************************************************************************
!Sorts an array arr(1:n) into ascending numerical order,,
!using the Quicksort algorithm. n is input; arr is replaced,,
!on output by its sorted rearrangement.
!Parameters: M is the size of subarrays sorted by straight
!insertion and NSTACK is the required auxiliary storage.
! Adapted from Numerical Recipes in Fortran Book
subroutine sort(n, arr)
implicit none
integer, intent(in) :: n
real(8), dimension(n) :: arr

integer, parameter :: M = 7
integer, parameter :: NSTACK = 50

integer :: i, ir, j, jstack, k, l
integer, dimension(NSTACK) :: istack

real(8) :: a, temp

jstack = 0
l = 1
ir = n
1 if (ir - l < M) then
   do j = l + 1, ir
      a = arr(j)
      do i = j - 1, l, -1
         if (arr(i) <= a) goto 2
         arr(i + 1) = arr(i)
      end do
      i = l - 1
      arr(i + 1) = a
   end do
   if (jstack == 0) return
   ir = istack(jstack)
   l = istack(jstack - 1)
   jstack = jstack - 2
else
   k = (l + ir) / 2
   temp = arr(k)
   arr(k) = arr(l + 1)
   arr(l + 1) = temp
   if (arr(l) > arr(ir)) then
      temp = arr(l)
      arr(l) = arr(ir)
      arr(ir) = temp
   end if
   if (arr(l + 1) > arr(ir)) then
   end if
2
temp = arr(l+1)
arr(l+1) = arr(ir)
arr(ir) = temp
end if
if (arr(l) > arr(l+1)) then
    temp = arr(l)
    arr(l) = arr(l+1)
    arr(l+1) = temp
end if
i = l+1
j = ir
a = arr(l+1)
3 continue
i = i+1
if (arr(i) < a) goto 3
4 continue
j = j-1
if (arr(j) > a) goto 4
if (j < i) goto 5
temp = arr(i)
arr(i) = arr(j)
arr(j) = temp
goto 3
5 arr(l+1) = arr(j)
arr(j) = a
jstack = jstack + 2
if (jstack > NSTACK) pause 'NSTACK too small in sort'
if (ir - i + 1 >= j - 1) then
    istack(jstack) = ir
    istack(jstack - 1) = i
    ir = j - 1
else
    istack(jstack) = j - 1
    istack(jstack - 1) = l
    l = i
end if
end if
goto 1
end subroutine sort
SUBROUTINE SORT2

! Sorts an array arr(1:n) into ascending order using
! Quicksort, while making the corresponding rearrangement
! of the array brr(1:n).
! Adapted from Numerical Recipes in Fortran Book

SUBROUTINE SORT2(N, ARR, BRR)
IMPLICIT NONE

INTEGER, INTENT(IN) :: N
REAL(8), DIMENSION(N) :: ARR
INTEGER, DIMENSION(N) :: BRR

INTEGER, PARAMETER :: M = 7
INTEGER, PARAMETER :: NSTACK = 50

INTEGER :: I, IR, J, JSTACK, K, L
INTEGER, DIMENSION(NSTACK) :: ISTACK
REAL(8) :: A, TEMP
INTEGER :: B, TEMPB

JSTACK = 0
L = 1
IR = N

1 IF(IR - L < M) THEN
   DO J = L + 1, IR
      A = ARR(J)
      B = BRR(J)
      DO I = J - 1, L, -1
         IF(ARR(I) <= A) GO TO 2
         ARR(I+1) = ARR(I)
         BRR(I+1) = BRR(I)
      END DO
      I = L - 1
   2 ARR(I+1) = A
   IR = I + 1
   GOTO 1
brr(i+1) = b
end do
if (jstack == 0) return
ir = istack(jstack)
l = istack(jstack-1)
jstack = jstack-2
else
k = (l+ir)/2
    temp = arr(k)
    arr(k) = arr(l+1)
    arr(l+1) = temp
    tempb = brr(k)
    brr(k) = brr(l+1)
    brr(l+1) = tempb
if(arr(1) > arr(ir)) then
    temp = arr(1)
    arr(1) = arr(ir)
    arr(ir) = temp
    tempb = brr(1)
    brr(1) = brr(ir)
    brr(ir) = tempb
end if
if(arr(l+1) > arr(ir)) then
    temp = arr(l+1)
    arr(l+1) = arr(ir)
    arr(ir) = temp
    tempb = brr(l+1)
    brr(l+1) = brr(ir)
    brr(ir) = tempb
end if
if(arr(1) > arr(l+1)) then
    temp = arr(1)
    arr(1) = arr(l+1)
    arr(l+1) = temp
    tempb = brr(1)
    brr(1) = brr(l+1)
    brr(l+1) = tempb
end if
i = l+1
j = ir
a = arr(l+1)
b = brr(l+1)

3 continue
i = i+1
if(arr(i) < a) goto 3

4 continue
j = j−1
if(arr(j) > a) goto 4
if(j < i) goto 5
temp = arr(i)
arr(i) = arr(j)
arr(j) = temp
tempb = brr(i)
brr(i) = brr(j)
brr(j) = tempb
goto 3

5 arr(l+1) = arr(j)
arr(j) = a
brr(l+1) = brr(j)
brr(j) = b
jstack = jstack+2
if(jstack > NSTACK) pause 'NSTACK too small in sort2'
if(ir−i+1 >= j−l) then
    istack(jstack) = ir
    istack(jstack−1) = i
    ir = j−1
else
    istack(jstack) = j−1
    istack(jstack−1) = l
    l = i
end if
end if
goto 1
end subroutine sort2

dend module array_tools
Listing A.9: Input Parameters

200  n_b  % number of asset grid points

30   n_y  % number of endowment grid points

1000 n_samples % number of samples in simulation

1500 n_periods % number of periods for each sample in simulation

0.90 beta % discount factor

2.0  sigma % risk aversion

0.01 r % risk free rate

0.95 rho % persistence of output

0.027 sigma_e % std dev of innovation to output

0.083 lambda % output penalty if default

0.222222 tauL % tax rate, low type

0.50 tauH % tax rate, high type

0.040 piL % prob of turnover, low type

0.040 piH % prob of turnover, high type

−0.12 b_min % minimum asset position

0.0  b_max % maximum asset position

1.0  b_scale % controls interval between asset grid % points

3.0  y_width % range of y = [mean − y_width*sd_y, 5 mean + y_width*sd_y]
new_v0  % if = 1, initialize value functions
% with 0, if = 0, initialize val
% guess_v*.txt files
A.1.3 MATLAB CODES

These Matlab codes then use the data from the value function iteration and the model simulation to do the various plots and estimation of statistics. The code plot_results_statistics.m uses the Matlab function read_data.m to import the data.

Listing A.10: Matlab Codes for plots and statistics

```matlab
% SELECT 1000 SAMPLES OF 32 PERIODS FROM 1500 PERIODS TO MATCH . .
% NIGERIA. No restriction on default
% This code calculates the statistics used in the second . .
% chapter of the thesis

clear all
close all
clc

% get parameters
p = read_data('params.txt');

% get value functions and policy functions
v = read_data('vfi_data.txt')

% get simulation data
d = read_data('sim_data.txt')

fn = 0;

% value function: v(b, y, h, type)
[n_b, n_y, n_h, n_t] = size(v.v);

% samples and periods
[n_periods, n_sample] = size(d.sim_b);

% PLOT
fn = fn + 1; figure(fn); clf;
i_b2 = round(0.5*n_b);
hold on
plot(v.y_grid, -squeeze(v.bn(i_b2,:,: ,1,1)), 'b-', 'LineWidth',2)
hold off
xlabel('endowment, log y')
```
ylabel('−b')
title('−b' policy function, h = 0, low type')
label = sprintf('b = %f', v.b_grid(i_b2));
legend(label)

% before computing simulation averages
% drop initial 200 observations for each sample
T0 = 200;
sim_q = d.sim_q(T0+1:end,:);
sim_pd = d.sim_pd(T0+1:end,:);
sim_d = d.sim_d(T0+1:end,:);
sim_type = d.sim_type(T0+1:end,:);
n_periods = n_periods - T0;
sim_y = log(d.sim_output(T0+1:end,:));
sim_bn = d.sim_bn(T0+1:end,:);
sim_c = log(d.sim_c(T0+1:end,:));

% calculating trade balance
sim_tau = zeros(size(sim_type));
sim_tau(sim_type == 1) = p.tauL;
sim_tau(sim_type == 2) = p.tauH;
sim_yy=(d.sim_output(T0+1:end,:));
sim_cc=(d.sim_c(T0+1:end,:));
tb_y = ((1-sim_tau).*sim_yy - sim_cc)/sim_yy;

% calculating spread
sim_r = 1./sim_q - 1; % interest rate
cs = sim_r - p.r; % credit spread

% expected default from change in type
ch_L_to_H_default = (sim_type(1:end-1,:)==1 & sim_type(2:end,:)==2 & sim_d(2:end,:)==1);
ch_L_to_H = (sim_type(1:end-1,:)==1 & sim_type(2:end,:)==2);
ch_H_to_L_default = (sim_type(1:end-1,:)==2 & sim_type(2:end,:)==1 & sim_d(2:end,:)==1);
ch_H_to_L = (sim_type(1:end-1,:)==2 & sim_type(2:end,:)==1);
end,:) == 1);

num_L_to_H_defaults = sum(sum(ch_L_to_H_default));
num_L_to_H = sum(sum(ch_L_to_H));
L_to_H_def_rate = num_L_to_H_defaults / num_L_to_H

num_H_to_L_defaults = sum(sum(ch_H_to_L_default));
num_H_to_L = sum(sum(ch_H_to_L));
H_to_L_def_rate = num_H_to_L_defaults / num_H_to_L

%Select data when for only less corrupt
for j=0:39
    h=32;
    for m=1:1000;
        if sim_type(j*h+1:(j+1)*h,m)==1
            yolo_L(:,m) =sim_y(j*h+1:(j+1)*h,m);
            type_L(:,m) =sim_type(j*h+1:(j+1)*h,m);
            colo_L(:,m) =sim_c(j*h+1:(j+1)*h,m);
            csolo_L(:,m) =cs(j*h+1:(j+1)*h,m);
            tb_yolo_L(:,m)=tb_y(j*h+1:(j+1)*h,m);
            D_L(:,m) =sim_d(j*h+1:(j+1)*h,m);
            pd_L(:,m) =sim_pd(j*h+1:(j+1)*h,m);
        end
    end
end

%Select data when for only more corrupt
for j=0:39
    h=32;
    for m=1:1000;
        if sim_type(j*h+1:(j+1)*h,m)==2
            yolo_H(:,m) =sim_y(j*h+1:(j+1)*h,m);
            type_H(:,m) =sim_type(j*h+1:(j+1)*h,m);
            colo_H(:,m) =sim_c(j*h+1:(j+1)*h,m);
            csolo_H(:,m) =cs(j*h+1:(j+1)*h,m);
            tb_yolo_H(:,m)=tb_y(j*h+1:(j+1)*h,m);
            D_H(:,m) =sim_d(j*h+1:(j+1)*h,m);
        end
    end
end
pd_H(:,m) = \text{sim}_pd(j \cdot h + 1:(j + 1) \cdot h,m);
end
end

% Select data for both types—unconditional
for j=0:39
h=32;
for m=1:1000;
yolo_U(:,m) = \text{sim}_y(j \cdot h + 1:(j + 1) \cdot h,m);
type_U(:,m) = \text{sim}_\text{type}(j \cdot h + 1:(j + 1) \cdot h,m);
colo_U(:,m) = \text{sim}_c(j \cdot h + 1:(j + 1) \cdot h,m);
csolo_U(:,m) = \text{cs}(j \cdot h + 1:(j + 1) \cdot h,m);
tb_yolo_U(:,m)=tb_y(j \cdot h + 1:(j + 1) \cdot h,m);
D_U(:,m) = \text{sim}_d(j \cdot h + 1:(j + 1) \cdot h,m);
pd_U(:,m) = \text{sim}_pd(j \cdot h + 1:(j + 1) \cdot h,m);
end
end

% HP filtering data for quarters
lambda = 1600;
% Less corrupt
y_trend_L = \text{hpfilter}(yolo_L\text{,}lambda);
yy_dev_L = yolo_L–y_trend_L
std_y_L = \text{mean}(\text{std}(yy_dev_L))\cdot100;

c_trend_L = \text{hpfilter}(colo_L\text{,}lambda);
c_dev_L = colo_L–c_trend_L
std_c_L = \text{mean}(\text{std}(c_dev_L))\cdot100;

cs_trend_L = \text{hpfilter}(csolo_L\text{,}lambda);
cs_dev_L = csolo_L–cs_trend_L
std_cs_L = \text{mean}(\text{std}(cs_dev_L))\cdot100;

tb_trend_L = \text{hpfilter}(tb_yolo_L\text{,}lambda);
tb_dev_L = tb_yolo_L–tb_trend_L

219
\[
\text{std}_\text{tb}_L = \text{mean}(\text{std}(\text{tb}_\text{dev}_L)) \times 100;
\]

%%% corrrelations
\[
\text{corr}_y\text{c}_L = \text{corrcoef}(\text{yy}_\text{dev}_L, \text{c}_\text{dev}_L);
\text{corr}_y\text{tb}_L = \text{corrcoef}(\text{yy}_\text{dev}_L, \text{tb}_\text{dev}_L);
\text{corr}_y\text{cs}_L = \text{corrcoef}(\text{yy}_\text{dev}_L, \text{cs}_\text{dev}_L);
\text{corr}_{\text{tb}}\text{cs}_L = \text{corrcoef}(\text{tb}_\text{dev}_L, \text{cs}_\text{dev}_L);
\]

%%% more corrupt
\[
\text{y}_\text{trend}_H = \text{hpfilter}(\text{yolo}_H, \lambda);
\text{yy}_\text{dev}_H = \text{yolo}_H - \text{y}_\text{trend}_H;
\text{std}_\text{y}_H = \text{mean}(\text{std}(\text{yy}_\text{dev}_H)) \times 100;
\text{c}_\text{trend}_H = \text{hpfilter}(\text{colo}_H, \lambda);
\text{c}_\text{dev}_H = \text{colo}_H - \text{c}_\text{trend}_H;
\text{std}_\text{c}_H = \text{mean}(\text{std}(\text{c}_\text{dev}_H)) \times 100;
\text{cs}_\text{trend}_H = \text{hpfilter}(\text{csolo}_H, \lambda);
\text{cs}_\text{dev}_H = \text{csolo}_H - \text{cs}_\text{trend}_H;
\text{std}_\text{cs}_H = \text{mean}(\text{std}(\text{cs}_\text{dev}_H)) \times 100;
\text{tb}_\text{trend}_H = \text{hpfilter}(\text{tb}\text{yolo}_H, \lambda);
\text{tb}_\text{dev}_H = \text{tb}_\text{yolo}_H - \text{tb}_\text{trend}_H;
\text{std}_\text{tb}_H = \text{mean}(\text{std}(\text{tb}_\text{dev}_H)) \times 100;
\]

%%% correlation
\[
\text{corr}_y\text{c}_H = \text{corrcoef}(\text{yy}_\text{dev}_H, \text{c}_\text{dev}_H);
\text{corr}_y\text{tb}_H = \text{corrcoef}(\text{yy}_\text{dev}_H, \text{tb}_\text{dev}_H);
\text{corr}_y\text{cs}_H = \text{corrcoef}(\text{yy}_\text{dev}_H, \text{cs}_\text{dev}_H);
\text{corr}_{\text{tb}}\text{cs}_H = \text{corrcoef}(\text{tb}_\text{dev}_H, \text{cs}_\text{dev}_H);
\]

%%% UNCONDITIONAL
\[
\text{y}_\text{trend}_U = \text{hpfilter}(\text{yolo}_U, \lambda);
\text{yy}_\text{dev}_U = \text{yolo}_U - \text{y}_\text{trend}_U;
\text{std}_\text{y}_U = \text{mean}(\text{std}(\text{yy}_\text{dev}_U)) \times 100;
\text{c}_\text{trend}_U = \text{hpfilter}(\text{colo}_U, \lambda);
\text{c}_\text{dev}_U = \text{colo}_U - \text{c}_\text{trend}_U;
\]
\[
\text{std}_cU = \text{mean}(\text{std}(c_{\text{dev}}U)) \times 100;
\]

\[
c_{\text{trend}}U = \text{hpfilter}(c_{\text{solo}}U, \lambda);
\]

\[
c_{\text{dev}}U = c_{\text{solo}}U - c_{\text{trend}}U;
\]

\[
\text{std}_{c}U = \text{mean}(\text{std}(c_{\text{dev}}U)) \times 100;
\]

\[
tb_{\text{trend}}U = \text{hpfilter}(tb_{\text{yolo}}U, \lambda);
\]

\[
tb_{\text{dev}}U = tb_{\text{yolo}}U - tb_{\text{trend}}U;
\]

\[
\text{std}_{tb}U = \text{mean}(\text{std}(tb_{\text{dev}}U)) \times 100;
\]

\[
\text{corr}_{y_{c}}U = \text{corrcoef}(yy_{\text{dev}}U, c_{\text{dev}}U);
\]

\[
\text{corr}_{y_{tb}}U = \text{corrcoef}(yy_{\text{dev}}U, \text{tb}_{\text{dev}}U);
\]

\[
\text{corr}_{y_{cs}}U = \text{corrcoef}(yy_{\text{dev}}U, c_{\text{dev}}U);
\]

\[
\text{corr}_{tb_{cs}}U = \text{corrcoef}(tb_{\text{dev}}U, c_{\text{dev}}U);
\]

\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%

\% Credit Spreads
\% \% mean credit spread, overall
\% get credit spreads for the types
\% mean\_cs = 4*100*mean(mean(c_{\text{solo}}U)); \% annual
\% cs\_L = c_{\text{solo}}L;
\% cs\_H = c_{\text{solo}}H;
\% mean\_cs\_L = 4*100*mean(mean(cs\_L)); \% annual
\% mean\_cs\_H = 4*100*mean(mean(cs\_H)); \% annual

\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%

\% Default Probabilities
\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%

\% mean default probability, overall
\% default probabilities by type
\% mean\_pd = 4*100*mean(mean((pd\_U)))/\% annual
\% mean\_pd\_L = 4*100*mean(mean(pd\_L)); \% annual
\% mean\_pd\_H = 4*100*mean(mean(pd\_H)); \% annual

\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%\%

\% Avg # of Default Occurrences Every Year
mean defaults per year (4 periods per year)
mean defaults by type
mean defaults per year (4 per year)

\[
\text{mean}_D = 4 \times 100 \times \text{mean}(	ext{mean}(D_U)); \quad \text{annual}
\]
\[
\text{mean}_D_L = 4 \times 100 \times \text{mean}(	ext{mean}(D_L)); \quad \text{annual}
\]
\[
\text{mean}_D_H = 4 \times 100 \times \text{mean}(	ext{mean}(D_H)); \quad \text{annual}
\]

% statistics
\[
\text{stats} = \{\}
\]
\[
\text{stats}.\text{mean}_\text{cs} = \text{mean}_\text{cs}
\]
\[
\text{stats}.\text{mean}_\text{cs}_L = \text{mean}_\text{cs}_L
\]
\[
\text{stats}.\text{mean}_\text{cs}_H = \text{mean}_\text{cs}_H
\]
\[
\text{stats}.\text{mean}_\text{pd} = \text{mean}_\text{pd}
\]
\[
\text{stats}.\text{mean}_\text{pd}_L = \text{mean}_\text{pd}_L
\]
\[
\text{stats}.\text{mean}_\text{pd}_H = \text{mean}_\text{pd}_H
\]
\[
\text{stats}.\text{mean}_D = \text{mean}_D
\]
\[
\text{stats}.\text{mean}_D_L = \text{mean}_D_L
\]
\[
\text{stats}.\text{mean}_D_H = \text{mean}_D_H
\]

\text{stats}

% statistics less corrupt
\[
\text{stats}_L = \{\}
\]
\[
\text{stats}_L.\text{std}_y_L = \text{std}_y_L ;
\]
\[
\text{stats}_L.\text{std}_\text{c}_L = \text{std}_\text{c}_L ;
\]
\[
\text{stats}_L.\text{std}_\text{cs}_L = 4 \times \text{std}_\text{cs}_L ;
\]
\[
\text{stats}_L.\text{std}_\text{tb}_L = \text{std}_\text{tb}_L ;
\]
\[
\text{stats}_L.\text{corr}_y_\text{c}_L = \text{corr}_y_\text{c}_L (1,2);
\]
\[
\text{stats}_L.\text{corr}_y_\text{cs}_L = \text{corr}_y_\text{cs}_L (1,2);
\]
\[
\text{stats}_L.\text{corr}_y_\text{tb}_L = \text{corr}_y_\text{tb}_L (1,2);
\]
\[
\text{stats}_L.\text{corr}_\text{tb}_\text{cs}_L = \text{corr}_\text{tb}_\text{cs}_L (1,2);
\]

\text{stats}_L

% statistics more corrupt
\[
\text{stats}_H = \{\}
\]
\[
\text{stats}_H.\text{std}_y_H = \text{std}_y_H ;
\]
\[
\text{stats}_H.\text{std}_\text{c}_H = \text{std}_\text{c}_H ;
\]
stats.H.std_cs.H = 4*std_cs.H;
stats.H.corr_y_c.H = corr_y_c.H(1,2);
stats.H.corr_y_cs.H = corr_y_cs.H(1,2);
stats.H.corr_y_tb.H = corr_y_tb.H(1,2);
stats.H.corr_tb_cs.H = corr_tb_cs.H(1,2);

stats_H

% statistics unconditional on type
stats.U = {};
stats.U.std_y.U = std_y.U;
stats.U.std_c.U = std_c.U;
stats.U.corr_y_c.U = corr_y_c.U(1,2);
stats.U.corr_y_cs.U = corr_y_cs.U(1,2);
stats.U.corr_y_tb.U = corr_y_tb.U(1,2);
stats.U.corr_tb_cs.U = corr_tb_cs.U(1,2);

stats_U

% calculate defaults above long-run mean of output.
DD_L = sim_d(sim.type == 1); % type - less corrupt
DD_H = sim_d(sim.type == 2); % type - more corrupt

% default above long run mean
Y_L = sim_y(sim.type == 1); % type - less corrupt
Y_H = sim_y(sim.type == 2); % type - more corrupt
D_LA = DD_L(Y_L > 0.0040); % above long-run mean of output
D_LB = DD_L(Y_L <= 0.0040); % defaults below mean output
DefLA = (sum(D_LA)/sum(DD_L))*100% less corrupt percentage
D_HA = DD_H(Y_H > 0.0040); % more corrupt defaults above mean y
D_HB = DD_H(Y_H <= 0.0040);
DefHA = (sum(D_HA)/sum(DD_H))*100% percentage
DA=sim_d(sim_y>0.0040); % all defaults above mean output
DefA=(sum(DA)/sum(sum(sim_d)))*100

% select speeds before and after default
for m=1:1000
    for j=5:1296
        if sim_d(j,m)==1
            css(:,m)=cs(j-4:j+4,m);
        end
    end
end
css(:,all(any(css),1))=[];
% removes all columns with all zero
css1=mean(css(:,~=0));
css1=mean(css,2);
css2=css1./css1(1,1); % grow rate of spread
fn = fn+1; figure(fn); clf;
hold on
plot(css2)

% select borrowing before and after default
for m=1:1000
    for j=5:1296
        if sim_d(j,m)==1
            bn(:,m)=sim_bn(j-4:j+4,m);
        end
    end
end
bn(:,all(any(bn),1))=[];
% removes all columns with all zero
bn1=mean(bn(:,~=0));
bn1=mean(bn,2);
bn2=bn1./bn1(1,1); % grow rate of borrowing
fn = fn+1; figure(fn); clf;
hold on
plot(bn2)
% Default space - mesh size of b is small, need large size of b

dd1 = ((v.d(:,:,1,1)));  
dd2 = ((v.d(:,:,1,2)));  
fn = fn+1; figure(fn); clf;
hold on

colormap([1 1 1;0 0 0])

s1=mesh(v.b_grid,v.y_grid,dd1');  
axis([min(v.b_grid),max(v.b_grid),min(v.y_grid),max(v.y_grid),0,1]);
view(0,90);

alpha(s1, 0.5); % 0.5 is gray
hold on

s2=mesh(v.b_grid,v.y_grid,dd2');
axis([min(v.b_grid),max(v.b_grid),min(v.y_grid),max(v.y_grid),0,1]);
view(0,90);

xlabel('Bond', 'FontSize',12);
ylabel('Output', 'FontSize',12);

alpha(s2, 0.0); % 0 is black
hold off
Listing A.11: Matlab function for importing simulated data for plots

```matlab
function [ args ] = read_data( filename )

% READ_DATA Reads data from text file.
% READ_DATA(filename) returns a 1x1 cell array containing all
% the data stored in FILENAME. FILENAME is assumed to specify
% a text file in which the data is stored in the same format as
% that used by READ_DATA.
% Author: Patrick Macnamara
% https://sites.google.com/site/pmacnama/

if nargin ~= 1
    error( 'usage: [ args ] = read_data( filename )' );
end

args = {}; % fopen returns fid >= 0 if successful, -1 if not
fid = fopen( filename, 'r' );

while feof(fid) == 0

    % try to read name of variable and number of dimensions
    C = textscan( fid, '%s %d', 1 );

    % if successful, then read rest of data for this variable
    % if unsuccessful, then there is no more data to read
    if feof(fid) == 0
        % get variable name
        arg_name = C{1}{1};

        % get number of dimensions
        nd = C{2};

        % read rest of info
        D = textscan( fid, '%d', nd );
        d = D{1}';

        % get number of elements in array
        N = 1;
    
```
for i = 1:nd
    N = d(i) * N;
end

% read values:
row_data = textscan(fid, '%f', N);
if (numel(row_data{1}) == N)
    arg_val = reshape(row_data{1}, d);
else
    fclose(fid);
    error('Invalid number of array elements stored ');
end

% store variable in struct
args.(arg_name) = arg_val;
end

fclose(fid);
end

% fclose returns 0 if successful, -1 if not
A.2 Chapter 3 Computer Codes

A.2.1 STATA CODES

Stata code used for the empirical results of this chapter of the thesis.

Listing A.12: Stata Do file

```
//import data limited_enforcement.dta
//COUNTRY RE AND FE; full sample
egen id = group(country)
tab year, gen(yr)
xtset country year
xtline lnrsgdp ENF
//ssc install sutex, replace
sutex lnrsgdp ENF creditdepth, minmax

xtreg lnrsgdp ENF, re
eststo est1
xtreg lnrsgdp ENF, fe
eststo est2
xtreg lnrsgdp creditdepth, re
eststo est3
xtreg lnrsgdp creditdepth, fe
eststo est4
xtreg lnrsgdp ENF creditdepth, re
eststo est5
xtreg lnrsgdp ENF creditdepth, fe
eststo est6
xtreg lnrsgdp ENF creditdepth ENFCREDIT, fe
eststo est7
xtreg lnrsgdp ENF creditdepth ENFCREDIT, re
eststo est8
esttab est1 est2 est3 est4 est5 est6 est7 est8 using

//COUNTRY RE AND FE
//USING 36 COUNTRIES
```
//import data limited_enforcement_short.dta
xtset country year
xtline lnrngdp ENF

xtreg lnrngdp ENF, re
eststo est1

xtreg lnrngdp ENF, fe
eststo est2

xtreg lnrngdp creditdepth, re
eststo est3

xtreg lnrngdp creditdepth, fe
eststo est4

xtreg lnrngdp ENF creditdepth, re
eststo est5

xtreg lnrngdp ENF creditdepth, fe
eststo est6

xtreg lnrngdp ENF creditdepth ENF CREDIT, fe
eststo est7

xtreg lnrngdp ENF creditdepth ENF CREDIT, re
eststo est8

esttab est1 est2 est3 est4 est5 est6 est7 est8 using //TIME AND COUNTRY RE AND FE
//use limited_enforcement.dta; full sample
xtreg lnrngdp ENF yr2-yr9, re
eststo est1

xtreg lnrngdp ENF yr2-yr9, fe
eststo est2

xtreg lnrngdp creditdepth yr2-yr9, re
eststo est3

xtreg lnrngdp creditdepth yr2-yr9, fe
eststo est4

xtreg lnrngdp ENF creditdepth yr2-yr9, re
eststo est5
xtreg lnr gd p ENF credit depth yr2−yr9 ,fe
eststo est6
xtreg lnr gd p ENF credit depth ENFCREDIT yr2−yr9 ,fe
eststo est7
xtreg lnr gd p ENF credit depth ENFCREDIT yr2−yr9 ,re
eststo est8
esttab est1 est2 est3 est4 est5 est6 est7 est8

//TIME AND COUNTRY RE AND FE
//use limited_enforcement_short.dta”, 36 countries
xtreg lnr gd p ENF yr2−yr9 ,re
eststo est1
xtreg lnr gd p ENF yr2−yr9 ,fe
eststo est2
xtreg lnr gd p credit depth yr2−yr9 ,re
eststo est3
xtreg lnr gd p credit depth yr2−yr9 ,fe
eststo est4
xtreg lnr gd p ENF credit depth yr2−yr9 ,re
eststo est5
xtreg lnr gd p ENF credit depth yr2−yr9 ,fe
eststo est6
xtreg lnr gd p ENF credit depth ENFCREDIT yr2−yr9 ,fe
eststo est7
xtreg lnr gd p ENF credit depth ENFCREDIT yr2−yr9 ,re
eststo est8
esttab est1 est2 est3 est4 est5 est6 est7 est8
A.2.2 DYNARE CODES

We solve the Dynamic Stochastic General Equilibrium (theoretical) model in Dynare. In doing this we use the equilibrium conditions in Section (3.3.2.6) and the steady state in Appendix(3.5.6) as initial values. Below is the Dynare code for the model.

Listing A.13: Dynare code

% This solves the investment model
%-------------------------------------------------------------------%

% K is aggregate capital
% ke is entrepreneurial capital
% H aggregate is household labour
% He is entrepreneurila labour
% q is price of capital
% n is net worth
% i is investment
% default omegabb threshold
% entrepreneurial consumption
% household consumption
% Welf is welfare
% w is household wage rate
% we is entrepreneurial wage rate
% Y aggregate output
% C is total consumption
% r rental rate of capital
% Rb is lending rate
% rpBANK risk premium of lenders
% lev leverage
% PHI bankruptcy
entrepreneur’s share of capital output
lender’s share of capital output
A productivity

\[ \text{var } K \text{ ke } H \text{ He } h \text{ q n i omegabb ce cc Welf}\ C c \text{ Ce w we Y r I} \]

... C Bankruptcy Rb rpBANK lev PHI phi f g A;

varexo eA eN;% shocks

parameters alpha zeta beta delta varphi gamma eta S nu

.. \text{mu } p M \text{ rhoA StdeA StdeN zetaa Ass};

alpha = 0.36; %share of capital
zeta = 1-\alpha -0.0001; %share of household labour
beta = 0.99; %discount rate
delta = 0.02; %depreciation rate
gamma = 0.91; %survival rate of entrepreneur
eta = 0.1;
rhoA = 0.95;
StdeA = 0.01;
StdeN = 0.1;
S = 0.207;
nu = 3;2.52;
mu = 0.150; %verification cost parameter
p = pi;
M = -5*\text{S}^2;
 rhoStdA = 0.83;
StdeStdA = 0.19;
Ass = 1;
\( \varphi = 0.5; \)
\( \zeta_{aa} = 0.4; \) \%

\% limited enforcement, \( zeta \)

% MODEL BLOCK
model;

\( q*cc^{-1} = beta*(cc(+1)^{-1})*q(+1)*(1-delta)+r(+1); \)

% Euler equation
\( cc^{-1} = \nu/w; \) \%

\( ke = i*f - ce/q; \)
\( n = we + (ke(-1))*(q(1-delta)+r) - StdeN*eN; \)
\( K = (1-delta)*K(-1) + I(1-mu*PHI); \)
\( (1-eta)*cc + eta*ce + eta*i = Y; \)
\( q = (beta*gamma) * (r(+1) + q(+1)*(1-delta))* \)
\( \ldots (q(+1)*f(+1))/(1-q(+1)*g(+1)) ); \)
\( q = 1/(1 - mu*PHI - (mu*phi)*f/(1-PHI)*(1-zetaa)); \)
\( i = (1/(1-q*g)) * n; \)
\( Y = A*(K(-1)^{alpha})*(H^{zeta})*(He^{(1-alpha-zeta)}); \)
\( r = alpha*A*(K(-1)^{(alpha-1)})*(H^{zeta})*(He^{(1-alpha-zeta)}); \)
\( w = zeta*A*(K(-1)^{alpha})*H^{zeta(-1)})*He^{(1-alpha-zeta)}; \)
\( w = (1-alpha-zeta)*A*(K(-1)^{alpha})*H^{zeta})*He^{(-(alpha+zeta)}; \)
\( H = (1-eta)*h; \) \%

\% household labour
\( He = eta; \)

\% entrepreneurial labour
\( Cc = (1-eta)*cc; \) \%

\% household consumption
\( Ce = eta*ce; \)

\% entrepreneurial consumption
\( C = (1-eta)*cc + eta*ce; \)

\% aggregate consumption
\( I = eta*i; \)

Bankrupcy = PHI;

\( Rb = (q*i*omegabb*(1-zetaa))/(i-n); \) \%

% lending rate
rpBANK = Rb - 1; % risk premium of lender/bank
lev = (i-n)/n; % leverage
log(A) = rhoA*log(A(-1)) + eA;
PHI = normcdf((log(omegabb)-M)/S);
phi = normpdf((log(omegabb)-M)/S) / (omegabb*S);
g = (1-zetaa)*normcdf((log(omegabb)-M)/S - S) - PHI*mu + ...
   (1-zetaa)*(1-PHI)*omegabb;% lender's share
f = 1-mu*PHI- g;% entrepreneur's share of capital
Welf = log(cc)+nu*(1-h)+beta*Welf(+1);% welfare
end;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % %
% % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % % %

% initial values supplied
omegabb = 0.603892;
PHI = normcdf((log(omegabb)-M)/S);
phi = normpdf((log(omegabb)-M)/S) / (omegabb*S);
g = (1-zetaa)*normcdf((log(omegabb)-M)/S - S) - PHI*mu + ...
   (1-zetaa)*(1-PHI)*omegabb;
f = 1-mu*PHI- g;
q = 1/(1 - mu*PHI - (mu*phi)*f/(1-PHI)*(1-zetaa));
r = q*((1-beta*(1-delte))/beta);
H = .3;
He = eta;
h = .3/(1-eta);
K = (alpha/r)^(1/(1-alpha))*He^(1-alpha-zeta)/(1-alpha)*
   ... (H^(zeta/(1-alpha)));
Y = (K*alpha)*(H*zeta)*(He^(1-alpha-zeta));
i = (delta/(eta*(1-mu*0.01)))*K;
\[ n = (1 - g*q) * i; \]
\[ ke = (beta / q) * (eta*n - (1 - alpha - zeta) * Y); \]
\[ ce = q * (f*i - (ke / eta)); \]
\[ cc = (Y - eta*ce - eta*i) / (1 - eta); \]
\[ A = 1; \]
\[ w = nu * cc; \]
\[ Welf = -100; \% \text{welfare} \]
end;

steady;
check;
shocks;
 \begin{align*}
\text{var eA; stderr .01 ;} \\
\% \text{var eN; stderr 2;} \\
\end{align*}
end;

\text{stoch_simul(order=1, irf=30, hp_filter=1600);}