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Matti Koivuranta

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MATTI KOIVURANTA

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Abstract

This dissertation is comprised of three independent essays with the unifying theme of how uncertainty affects the macroeconomy. The first essay studies an incomplete market economy where the firm faces a non-trivial investment decision due to capital adjustment costs. The adjustment costs make the price of capital endogenous and help to explain the observed volatility of the returns to physical capital. The particular form of market incompleteness that is assumed in the essay is however not enough to match the observed price of risk. The essay contains also a technical contribution in showing how Arrow prices of contingent commodities can be used in computing the equilibrium in this class of models.

The second essay studies the effect of population aging on asset prices. The modeling framework features deterministic transition paths for demographic structure and level of government expenditures along with aggregate uncertainty at business cycle frequency. The demographic transition leads to a projected increase of in tax rates that are needed to finance the government expenditures. This requires higher savings rates from households which reduces volatility of consumption growth and reduces the price of aggregate risk.

The third essay is an empirical study which uses betting market data from the Swedish harness horse racing in conjunction with economic confidence indices. The main finding is that the risk attitudes of bettors that are reflected by the betting market data covary with the more traditional confidence measures in a reasonable way. The essay also contains a simple forecasting exercise which shows that the novel risk measure may also be useful in forecasting the industrial production. The results of the study are interpreted in terms of behavioral macroeconomics.

Keywords: asset prices, behavioral macroeconomics, betting markets, heterogeneous agents, incomplete markets, population aging

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Tiivistelmä

Tämä väitöskirja koostuu kolmesta erillisestä esseestä, joiden yhdistävä tekijä on epävarmuus ja sen vaikutukset makrotalouden ilmiöihin. Ensimmäisessä esseessä tarkastellaan taloutta, jossa markkinat ovat epätäydelliset ja fyysisen pääoman sopeuttamiskustannukset vaikuttavat yrityksen investointipäätökseen. Pääoman sopeuttamiskustannukset tekevät pääoman hinnasta endogeenisen muuttujan ja auttavat selittämään havaittua pääoman tuottojen volatiliteettia. Tutkimuksessa käytetyt markkinoiden epätäydellisyyteen johtavat oletukset eivät kuitenkaan riitä selittämään historiallisesti havaittua riskin hintaa. Essee sisältää myös teknisen kontribuution. Siinä osoitetaan, miten talouden tilasta riippuvien hyödykkeiden Arrow-hintoja voidaan hyödyntää tämän tyyppisten talouksien tasapainon numeerisessa ratkaisemisessa.

Toinen essee tarkastelee väestön ikääntymisen vaikutuksia varallisuushyödykkeiden hintoihin. Malli yhdistää väestörakenteen ja julkisten kulutusmenojen deterministisen muutoksen sekä suhdannevaihtelua kuvaavan kokonaistaloudellisen epävarmuuden. Väestörakenteen odotettu muutos johtaa julkisten kulutusmenojen kasvun myötä veroasteiden nousuun. Kotitaloudet joutuvat säästämään enemmän, mikä vähentää kulutuksen kasvun volatiliteettia ja kokonaistaloudellisen riskin hintaa.

Kolmas essee on empiirinen tutkimus, jossa käytetään havaintoaineistoa Ruotsin ravivedonlyöntimarkkinoilta sekä taloudellisia luottamusindikaattoreita. Tärkein tulos on että vedonlyöntiaineiston heijastama suhtautuminen riskiin näyttää olevan vuorovaikutuksessa perinteisten luottamusindikaattoreiden kanssa. Esseessä käytetään myös yksinkertaista aikasarjamallia, joka viittaa siihen, että vedonlyöntiaineiston perusteella laskettu riskiin suhtautumisen mitta voi olla hyödyllinen teollisuustuotannon ennustamisessa. Tuloksia tulkitaan behavioraalisen makrotaloustieteen valossa.

Asiasanat: behavioraalinen makrotaloustiede, epätäydelliset markkinat, heterogeeniset agentit, varallisuushinnat, vedonlyöntimarkkinat, väestön ikääntyminen

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Oulu, November 2016

Matti Koivuranta

List of original essays

This dissertation is based on the introductory chapter and the following three essays:

I Koivuranta M (2016) Asset pricing with incomplete markets and capital adjustment costs. Manuscript.
II Koivuranta M (2016) The effect of population aging on asset prices. Manuscript.
III Koivuranta M & Korhonen M (2016) Detecting animal spirits – evidence from the Swedish horse racing data. Manuscript.

Contents

1 Background

1.1 Theoretical foundations of general equilibrium with uncertainty

The roots of explicit consideration of risk within macroeconomics lie in the work of von Neumann & Morgenstern (1947) on preferences under uncertainty and the work of Arrow & Debreu (1954) on the theory of general equilibrium. Von Neumann and Morgenstern proved that under reasonable assumptions about the underlying preferences of an individual there exists a utility function whose expected value can be used to rank different lotteries. The linearity of the mathematical expectation retained the tractability of analysis but the structure nevertheless allowed consideration of risk aversion through the shape of the utility function. In particular, risk aversion is implied by a strictly concave utility function and risk love by a strictly convex utility function.

Arrow & Debreu (1954), on the other hand, made a groundbreaking contribution to the general equilibrium theory by proving the existence of an equilibrium in a relatively general economic model. Furthermore, Debreu (1959) showed that the potential domain of applications of the model could be vastly extended by generalizing the concept of a commodity. In particular, consideration of risk could be embedded into the model by conditioning commodities by occurrences of probabilistic events. Similarly, time dimension could be added by differentiating commodities by the time of delivery. Finally, after Arrow (1964) showed that the allocation of a multiple period Arrow-Debreu economy could be reached by sequential trade of one-period securities i.e. Arrow securities, the road was set for explicit general equilibrium to be introduced into macroeconomics.

1.2 Macroeconomics and general equilibrium

Keynesian economics was the dominant paradigm within macroeconomics in the 1950's and there were both technical and substantial challenges that slowed the introduction of general equilibrium under uncertainty into the field of macroeconomics. The macroeconomic models of the time were simultaneous equation models which did not directly relate to utility maximization or general equilibrium. There were theoretical underpinnings for individual equations such as the work of Patinkin (1956) on money demand and the work of Friedman (1956) and Modigliani (1954) on consumption

behavior but the macroeconomic models as a whole lacked microeconomic foundations. The lack of microeconomic foundations made the models vulnerable to the Lucas (1976) critique which remarks that the way in which an economy responds to a policy depends on the state of the economy and may therefore be poorly captured by empirical regularities of the historical data.

The introduction of the concept of a *recursive competitive equilibrium* by Lucas & Prescott (1971) and Lucas (1972) was an important theoretical development that admitted analysis of dynamic general equilibrium models with sound microeconomic foundations.[1] In this new class of macroeconomic models rational economic agents maximize their expected utilities subject to rational expectations and the market clearance reconciles the individual decisions. The adoption of the new paradigm was catalyzed by both the theoretical beauty of the new analytical machinery and the apparent failure of the Keynesian economic management policies in the middle of the stagflation of the 1970's.

Further developments have lead to dynamic stochastic general equilibrium (DSGE) models being the dominant modeling framework within macroeconomics. The initially conflicting views between the New Classical economists who adhered to the microeconomic foudations and Keynesian economists have been partly resolved by New Keynesian economics which utilizes the DSGE modeling framework but incorporates frictions such as monopolistic competition and price stickiness.[2]

A common feature of all the early studies within the new framework as well as most of the more recent studies is that individual decisions aggregate in such a way that a *representative agent* exist. This simplifies the analysis of the models since it is only necessary to consider the decision-making of a single agent but it also rules out all kinds of market incompleteness. For example on the household side the complete markets mean that the households are able to borrow against the future income and therefore can effectively insure themselves against individual-specific risks.

The representative agent DSGE models have been fairly successful in explaining the levels and variation of aggregate macroeconomic quantities such as output, consumption, investments and employment. In contrast, the baseline models display a well-known empirical failure in the pricing of risk. In particular, Mehra & Prescott (1985) show that with reasonable parameter values the model implies an equity premium that is an order of magnitude too low and coin the term *equity premium puzzle* for this observation. The

[1] The classic textbook on the related methods is Stokey & Lucas (1989).

[2] For a thorough introduction to New Keynesian economics see e.g. Woodford (2003).

puzzle is a consequence of the fact that within the representative agent model the equity premium is directly related to the covariance of per capita consumption growth and equity return. The covariance is simply too low in magnitude to rationalize the observed historical equity premium.

Different departures from the complete market assumption underlying the existence of a representative agent have been proposed partly in order to explain the equity premium puzzle. Without a representative agent it is in principle not the aggregate consumption that matters for the pricing of risk but all individual consumption processes. This makes it possible for idiosyncratic risk, i.e. income risk faced by individuals that is independent of the aggregate risk, to affect the outcome. The general problem in explaining the equity premium puzzle with incomplete markets is that in a dynamic environment rational agents self-insure against idiosyncratic risk by saving more (see e.g. Heaton & Lucas 1992). How effective insurance these buffer stock savings give depends on the details of the departures from the complete markets. The fact that the results of this literature are rather mixed is explained by the multitude of ways in which one can depart from the complete markets assumption.

Krusell & Smith (1997, 1998) extended the incomplete market literature to production economies with aggregate uncertainty. There is a computational problem because in principle the distribution of wealth across the agents becomes a part of the state of the economy and with a continuum of agents this distribution is an infinite-dimensional object. Krusell and Smith reconciled this problem by noting that with efficient enough self-insurance it is in practice sufficient to consider only the mean of the distribution. The modeling approach has been applied to studies of inequality, asset pricing (e.g. Storesletten *et al.* 2007), labor markets (e.g. Krusell *et al.* 2010) and firm dynamics (e.g. Khan & Thomas 2008).

In Essay I of this thesis I introduce a firm which makes investment decisions subject to capital adjustment costs into the two asset framework of Krusell & Smith (1997). This helps the model to display a more realistic quantity of risk as measured by e.g. the volatility of return to equity. Essay II combines the one asset framework of Krusell & Smith (1998) with non-stationarities which are designed to capture the essential features of aging population. The model is used to make predictions about the behavior of asset prices during the demographic transition.

1.3 Applications of the Arrow-Debreu model within gambling market studies

Another interesting set of applications of the Arrow-Debreu model includes studies on risk attitudes evident in gambling markets. In many ways gambling markets provide an ideal resemblance to a simple static Arrow-Debreu model of uncertainty. In particular there is a finite and typically small number of possible outcomes and all uncertainty related to a bet is typically resolved in a short period of time. This is in sharp contrast to e.g. stock market where the nature of uncertainty is less manageable, planning horizons of market participants vary and period-to-period returns of a stock depend not only on dividends but also on future price.

In comparison to surveys and experimental studies, that are sometimes used to study risk attitudes, the gambling markets have the favorable feature that they are real-life markets with real money at stake. Therefore the behavior of the market participants may be more genuine than answers to questionnaires or behavior in an artificial experiment.

The simple mapping between the data and the model admits straight-forward empirical estimation of risk attitudes of the bettors. Studies which utilize horse racing data to estimate risk preferences include e.g. Ali (1977), Jullien & Salanie (2000) and Snowberg & Wolfers (2010). Perhaps not surprisingly all these authors find that gamblers display risk-loving behavior.[3] The mirror-side of this finding is that the odds of horse race betting markets display a *favorite-longshot bias* which means that the average rate of return of a bet on a favorite is higher than the average rate of return of a bet on a longshot, i.e. a less likely winner. This bias in horse racing odds was first documented by Griffith (1949), and it still prevails. The persistence of the bias is made possible by the fact that the magnitude of the bias is not large enough for a gambler to break even with a simple strategy of betting extreme favorites.

In Essay III, which is a joint work with Dr. Marko Korhonen, we study time-variation of risk attitudes as measured from the Swedish harness horse racing markets. Our results display a meaningful relation between the betting market based risk attitude measure and the more conventional consumer confidence index. Furthermore, we suggest through a simple forecasting exercise that the betting market data may contain some useful predictive information about the aggregate economy beyond the more conventional measures.

[3]The observed risk-love is not a direct consequence of the fact that bookmakers offer actuarially unfair odds. This is because the articles study betting selections conditional on participation in the market.

2 Summary of essays

2.1 Essay I: Asset Pricing with Incomplete Markets and Capital Adjustment Costs

The essay studies an incomplete market economy where investment decisions are made by a firm who faces capital adjustment costs. The non-trivial role of the firm makes the price of capital endogenous. This helps the model to generate a more realistic quantity of risk, i.e. more variable return to equity, than previous incomplete market models with linear law of motion of capital (e.g. Krusell & Smith 1997).

On the other hand the endogenous price of capital provides a more realistic way to increase the quantity of risk than e.g. the assumption of stochastic depreciation of physical capital (e.g. Storesletten *et al.* 2007) because stochastic depreciation affects not only the return to capital but also the wage rate. I find that when a realistic quantity of risk is created endogenously through variation in the price of capital, the particular form of market incompleteness of my model is not enough to generate a realistic price of risk.

Solving the model numerically requires development of new computational techniques based on Krusell *et al.* (2010) that allow a non-trivial investment decision of a firm in an incomplete market economy.

2.2 Essay II: The Effect of Population Aging on Asset Prices

In this essay I study the effects of population aging on equilibrium asset prices. The study utilizes a general equilibrium model which features exogenous non-stationary transition paths for the ratio of working age population to total population, ratio of government debt to gross domestic product and ratio of government expenditures to gross domestic product. The exogenous transition paths are calibrated to roughly match the projections for the United States over the coming decades. The results can be interpreted more generally because qualitatively similar projections apply for most of the developed countries. In order to study questions of asset pricing the model also features aggregate uncertainty so that it can be seen as a non-stationary extension of the model in Krusell & Smith (1998).

I find that the preparation of households to older population and higher tax rates leads to a projected increase in savings which reduces the volatility of consumption

growth. The lower volatility of consumption growth reduces the price of risk. My model therefore projects a decrease in equity premium during the demographic transition.

The numerical solution of the model is complicated because of the simultaneous appearance of non-stationarities and aggregate uncertainty. The computation is carried out by merging the algorithms of Krusell & Smith (1998) and Auerbach & Kotlikoff (1987) in a novel way.

2.3 Essay III: Detecting Animal Spirits – Evidence from the Swedish Horse Racing Data

The study, which is co-authored by Dr. Marko Korhonen, explores whether there is a meaningful relation between broader macroeconomic conditions and risk attitudes that are measured from the betting market data. We use the Swedish harness horse racing win market data from years 1995-2013 to estimate a measure of risk aversion and use monthly subsamples to extract the time-variation of the measure. The estimation procedure utilizes the likelihood-based model of Jullien & Salanie (2000).

The important features of our measure include that it is based on market data rather than on surveys. Because our measure is market-based, it aggregates information of real economic decisions, making it inherently more truthful than answers to survey questions. Furthermore, the simple payoff structure and the lack of dynamic elements in the betting markets provide an almost ideal fit to the simple static Arrow-Debreu model, which is in contrast to most other market-based measures.

Our results show that the estimated risk measure is indeed related to the more conventional consumer confidence index. In particular, the representative bettor's behavior tends to be more risk-loving when consumer confidence is high than during times of low confidence.

We proceed to conduct a simple forecasting exercise where we forecast the monthly changes of industrial production index by utilizing conventional predictors, i.e. lags of industrial production index, OECD composite leading index and consumer confidence index, together with our measure based on betting market. The results suggest that our measure may contain useful predictive information about the broader economy that is independent of the more conventional measures.

We interpret our findings in terms of behavioral macroeconomics and economic psychology and suggest that our approach can be seen as a promising way to quantify the concept of *animal spirits* by Keynes (1936)

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I Koivuranta M (2016) Asset pricing with incomplete markets and capital adjustment costs. Manuscript.
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74. Mäläskä, Minna (2015) Co-creation of corporate brand through stakeholder relationships in B2B SMEs

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