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Demand for donkey hides and implications for global donkey populations

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Abstract:

Since antiquity donkey products have been attributed medicinal, rejuvenating and beautifying properties. In China medicinal and rejuvenating effects have been attributed to a gelatin, called ejiao, produced from donkey hides. In this paper, we analyse the demand for and supply of donkey hides. Ejiao has a long tradition in Traditional Chinese Medicine but it used to be a product reserved for the elite in Chinese society. A number of drivers have substantially increased the demand for ejiao over the last three decades. Economic development has made ejiao affordable for a much larger section of the Chinese population and it is now one of the most widely used products in Traditional Chinese Medicine. Over the last few years, the Chinese government has put policies in place to increase the use of Traditional Chinese Medicine, leading to a further increase in demand for ejiao. We conclude, therefore, that overall demand for ejiao is likely to continue to increase. We analyse the supply of donkey hides in China and globally. The rapid economic development in China has not only led to an increase in demand for ejiao but also to a rapid decrease in the domestic supply of donkeys. We use systems dynamics modelling to assess the potential of donkey farming in China in the medium and longer term. Our modelling exercise shows that even under very optimistic assumptions, current attempts to increase donkey farming in China will not meet the demand in the short term but has potential in the medium to longer term. Thus, international trade in donkey hides is likely to continue to play an important role, at least in the short term and a number of countries have given permission for donkey slaughter houses to be built. We use the systems dynamics model to assess the potential of countries to sustainably supply donkey hides over the next decade. The model shows that trade can contribute to the supply of donkey hides but it will be not possible to meet the current demand. Thus prices are likely to continue to increase. We conclude that there is currently a shortfall in supply of donkey hides that cannot be met either within China or from other countries. For this reason, fake ejiao products and illegal activities are likely to continue to characterise the donkey hide and ejiao markets.

1. Introduction

Today, donkeys are predominantly seen as companion animals in high-income countries and as working animals in low-income countries. However, since antiquity donkey products have been attributed medicinal, rejuvenating and beautifying properties. In China medicinal and rejuvenating effects have been attributed to a gelatin, called ejiao, produced from donkey hides. Today, ejiao is a very popular health tonic medicine in China (Ge, He and Hu, 2014). Its clinical uses within Traditional Chinese Medicine (TCM) are as a blood tonic for patients who suffer from dizziness, sallow complexion and/or palpitations, as a medicine that helps to stop bleeding of any type (it is commonly taken by some women at/around the time of menstruation) as well as a tonic that nourishes and moistens yin which is said to help against irritability, insomnia and dry lung coughs (Chinese Herbs Healing, no date; Yin and Yang House, no date). Ejiao is also ascribed anti-aging and rejuvenating effects (Wang *et al.*, 2012; Yang *et al.*, 2014). Demand for donkey hides for production of ejiao has led to rapid price increases for donkeys around the world, reports of illegal slaughter and trade of donkeys together with associated issues relating to the welfare and loss of working animals in many countries. A number of governments have restricted exports of donkeys or donkey hides to protect their domestic donkey populations. For example, Burkina Faso, Uganda, Tanzania, Botswana, Niger, Mali and Senegal have put restrictions on trade of donkeys and/or donkey hides as the increased prices have led to reports of widespread thefts of donkeys (Xinhua News Agency, 2017).

In this paper, we analyse the demand for and supply of donkey hides. Section 2 sets out the drivers for demand for ejiao and donkey hides over the last three decades and likely future developments in the demand for donkey hides for the production of ejiao. Section 3 analyses the supply of donkey hides in China and globally in the past and possible future sources for the supply of donkey hides. We use systems dynamics modelling to assess the potential of donkey farming in China as well as trade as a source of donkey hides. Section 4 examines the market impacts of the demand and supply changes over the last 3 decades. Section 5 models the potential for future donkey hide supply in China and Ethiopia. Section 6 concludes.

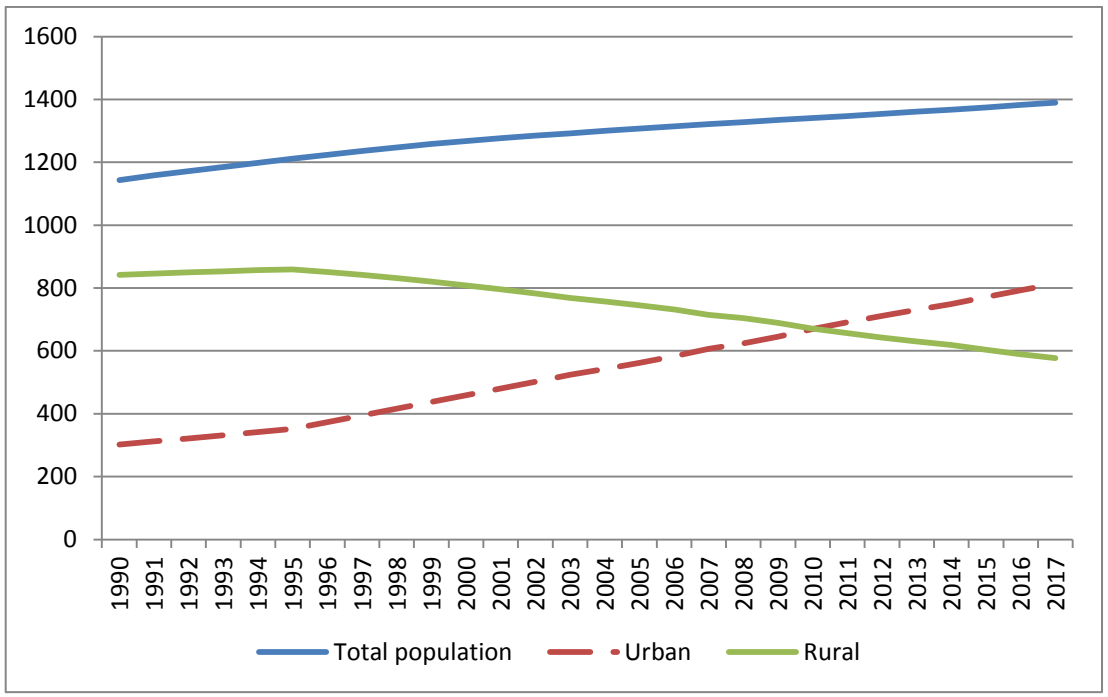
2. The demand for ejiao and donkey hides

The increase in the demand for ejiao is closely linked to a number of broad trends in China – demographic changes, strong economic growth, expansion of the health care sector, and more recently especially the TCM sector, by the Chinese government . These factors are discussed in more detail in the following sections.

Population trends

China's population continues at around 0.5 percent a year. Between 2016 and 2017 the population is estimated to have increased by over 7 million. All else being equal, in terms of general demand for goods and services, this increase in population can be expected to increase demand for products generally, including ejiao. Figure 1 shows total, urban and rural population in China between 1970 and 2017.

Figure 1: Population of China from 1990 to 2017 (in million)



Source: China Statistical Yearbook 2018

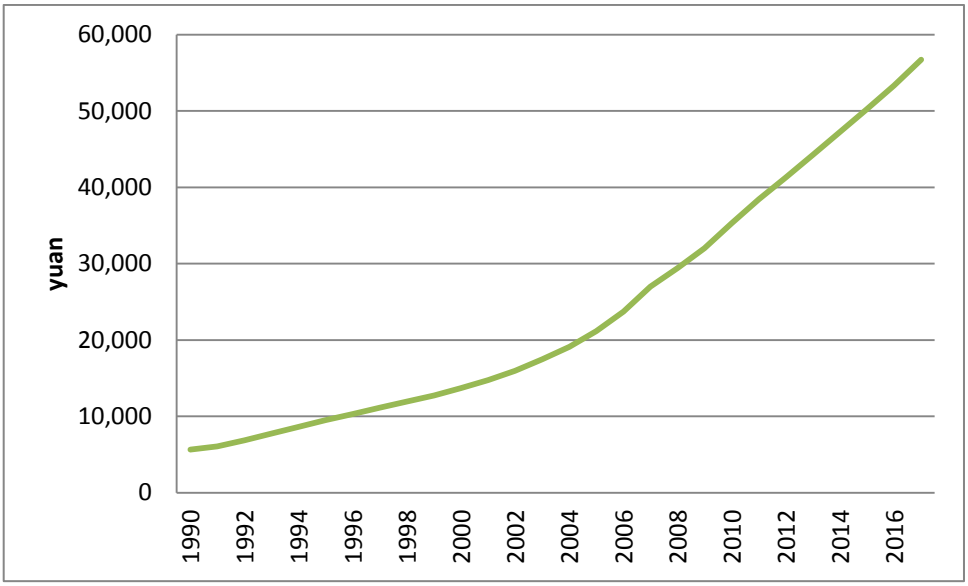
Between 1990 and 2017 the population in China increased by almost 250 million. Despite a reduced population growth rate between 2000 and 2017 China's population still increased by over 120 million between 2000 and 2017, and by over 7 million between 2016 and 2017 alone. In 2017 China's population was 1.39 billion. As a comparison, the total population of Sub-Saharan Africa was estimated at 1.06 billion in 2017 (World Bank, 2019). Even small increases in import demand by China can be sizable for individual African countries due to their much smaller overall populations and economies.

Two further population trends in China are relevant in relation to the demand for ejiao. Firstly, over the 27 years between 1990 and 2017 the proportion of the population living in urban areas has increased from 26 percent to 59 percent and in absolute terms the urban population of China increased by more than 500 million between 1990 and 2017 (National Bureau of Statistics of China, 2018). Secondly, as a result of the low birth rate and an increase in life-expectancy, the proportion of people over 65 years of age increased from 5.6 percent in 1990 to 11.4 percent in 2017 (National Bureau of Statistics of China, 2018). The impacts of these broader population trends on the demand for ejiao will be discussed in the following sections.

Income and health expenditure trends

Average incomes in China have increased rapidly since 1990. Figure 2 shows GDP per capita in constant yuan from 1990 to 2017. GDP per capital at constant yuan increased tenfold over this period.

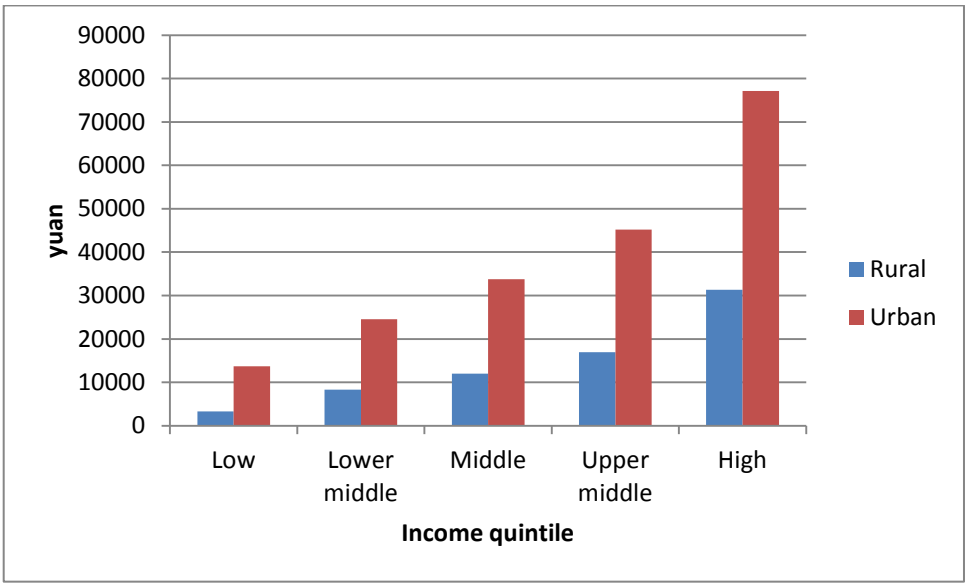
Figure 2: GDP per capita in constant yuan between 1990 and 2017



Source: World Bank National Accounts Data

Income distribution is quite uneven in China, especially between urban and rural areas(Han, Zhao and Zhang, 2016). Figure 3 shows the latest information on disposable income quintiles for urban and rural households. Demand for ejiao can be expected to come predominantly from the urban population.

Figure 3: Per capita disposable income by quintile for urban and rural household in 2017



Source: China Statistical Yearbook 2018

As countries become richer the percentage of health spending in total spending tends to increase (Farag *et al.*, 2012). In addition, with the increase in the percentage of the population that is 65 years and above health spending is also likely to be higher. Information on health care and medical expenditure is available for the years 2013 to 2017. Table 1 summarises the information.

Table 1: Per capita health care and total expenditure by Chinese households

	2013	2014	2015	2016	2017	% change 2013 to 2017
Total expenditure per capita (in yuan)	13,220	14,491	15,712	17,111	18,322	39%
Health Care and Medical Services (in yuan)	912	1,045	1,165	1,308	1,451	59%
% Health Care and Medical Services out of total expenditure	6.9%	7.2%	7.4%	7.6%	7.9%	

Source: China Statistical Yearbook 2018

Between 2013 and 2017 total average expenditure per capita increased by 39 percent but average health care and medical services expenditure per capita increased by 59 percent. Health care and medical services expenditure was 7.9 percent of total expenditure in 2017.

The main driver behind increases in household spending on health care is likely to be the increase in incomes. However, some commentators suggest that the widespread pollution in the big urban areas has made the Chinese urban population more health conscious which is likely to lead to higher health care spending, especially among urban residents (Butler, 2015).

The figures above relate to spending by households, which is often called out-of-pocket payments for healthcare. As noted in a report by OECD (OECD, 2017) out-of-pocket spending for healthcare is relatively high in China compared to other countries. However, over the last 15 years the increase in government provided healthcare has been even more significant.

Changes in the health system in China

Since the mid-2000s the healthcare system in China has undergone substantial changes. As a recent OECD report notes (OECD, 2017, p. 44):

"Access to healthcare has been improved by a dramatic expansion in health insurance coverage. Between 2004 and 2014, the coverage rate rose from around 200 million to over 1.3 billion people – the largest expansion of insurance coverage in human history."

Public health insurance coverage in China is now near universal. The insurance is publicly funded and provided by the local tiers of government. Health insurance covers primary and specialist healthcare, hospitals as well as medicines including both Western and TCM but the details of the implementation differ from region to region (Fang, no date; Nofri, 2015).

Participants of three focus groups in 2017 confirmed that the rules differed between regions but that the general principal is that a certain amount of money is loaded onto the health insurance card from local government. The money can be spent in hospitals, at doctors or at registered pharmacies. TCM plays an important role within the Chinese healthcare system. Of all outpatient treatments 20 percent are provided by TCM (Chung *et al.*, 2013). This proportion is higher in hospitals and lower in community care centres. TCM alternatives are particularly popular with

poorer sections of the population and those who are underinsured as TCM medicines tend to be cheaper than western medicines (Chung *et al.*, 2013).

The last two Five-Year-Plans, the 12th Five-Year Plan 2011-2015 and the 13th Five Year Plan 2016-2020, include as aims the support of TCM and improvement of the availability of TCM healthcare (Chung *et al.*, 2013; KPMG, 2016). In 2016, the Chinese government also published the Development Plan of Traditional Chinese Medicine Healthcare Services (2015-2020) in which further budgetary and tax policies to support TCM were announced (KPMG, 2016). In July 2017 a new law on TCM came into effect with the aim to increase the use of TCM within the publicly funded Chinese health system (*Law of the People's Republic of China on Traditional Chinese Medicine*, 2017).

In an online survey with 781 Chinese users of ejiao that we ran in 2018, 18 percent of respondents indicated that they always use their health insurance card, 15 percent that they do not use their health insurance cards with the remainder sometimes using the health insurance card to buy ejiao.

The increase in demand for ejiao has to be seen in the context of these general trends in population, income and spending as well as in relation to the changes in the health care system in China since 2000.

Demand for ejiao

Information on the demand for ejiao is scarce. Some information is available about the sale of ejiao through retail pharmacies. A survey of pharmacies in Shanghai and Guangzhou found that ejiao is the most popular medicine in the category of health tonics (Ge, He and Hu, 2014). According to Sinohealth, a market research institute specialising in the healthcare sector, sales of ejiao through retail pharmacies were 6.5 billion yuan (about 1bn USD)in 2015 (Customs Information Network, 2017). Ejiao was the medicine with the largest value of sales through retail pharmacies, a 32.8 percent increase compared to the previous year. This large increase in the value of sales is at least partly driven by price increases (see section 4) but also possibly partly by an increase in the volume of sales.

Ejiao is also an ingredient in lifestyle products, such as healthy snacks or anti-aging drinks (Yang *et al.*, 2014) and as one ingredient into more complex traditional Chinese medicines that are used to treat a wide variety of conditions, such as menopausal syndrome (Yang *et al.*, 2012) and gastric cancer (Chen *et al.*, 2018), to prevent miscarriage (Li *et al.*, 2014) or to treat Haemolysis and Anaemia (Chu *et al.*, 2014). These sources suggest that the market for demand is diverse but little reliable information is available about the overall demand for ejiao.

Media reports suggest that the overall size of the market was around 5,000 tonnes in 2015 (reported at the start of 2016) but an article in the International Journal of Nanomedicine by researchers from Shandong states a figure of 6,000 tonnes of total production in 2015 (Xinhua News Agency, 2016; Li *et al.*, 2017). Other reports suggest that production increased from 3,200 tonnes in 2013 to 5,600 tonnes in 2016 (Xinhua News Agency, 2017).

Based on the fact that between 1990 and 2017 the Chinese population increased by over 20 percent, that per capita income has increased tenfold over this period and that health expenditure increased more than total expenditure, it seems very likely that production of and demand for ejiao has increased by substantially more than the increase in income i.e. more than tenfold over the last

three decades. Given the current maximum estimate of a production of 6000 tonnes, production of ejiao was likely below 500 tonnes in 1990.

It is likely that demand will continue to increase over the next few years. A law on TCM came into effect on 1st July 2017. It aims to increase the demand for TCM, and thus likely also ejiao, mainly through health practitioners. Continued broad demographic trends in urbanisation and an ageing and wealthier population are likely to have larger impacts on retail sales.

Demand for donkey hides

Donkey hides are the main ingredient of ejiao. One estimate suggests that to produce 5,000 tonnes of ejiao about 4 million donkey hides are required (Wang *et al.*, 2012)(Xinhua News Agency, 2016). Thus on average 1.25 kg of ejiao could be produced from one donkey hide. An annual production of 6,000 tonnes of ejiao would require 4.8 million donkey hides. Another report claims that to produce one tonne of ejiao three tonnes of dried donkey hides are required.[1] A dried donkey hide is estimated by the same report to weigh 8 kg. These figures suggest that to produce 5,000 tonnes of ejiao 15,000 tonnes of dried donkey hides are required. With an average weight of 8 kg per hide the required number of donkey hides would translate into a requirement of 1.9 million donkeys for 5,000 tonnes and 2.3 million donkeys for 6,000 tonnes.

As demand for ejiao has increased rapidly, so has the demand for donkey hides. It is likely that the demand for donkey hides in ejiao production increased more rapidly than incomes at constant prices as the percentage of health spending increases as incomes increase. If we adopt a conservative approach and assume that the use of donkey hides increased at the same rate as GDP at constant prices we can derive indicative numbers for the use of donkey hides for ejiao production between 1990 and 2016 under a) the assumption that in 2016 4.8 million donkey hides were used and b) that 2.3 million donkey hides were used. Table 2 shows the resulting estimated use of donkey hides for ejiao production:

Table 2: Indicative estimates of the number of donkey hides used in ejiao production between 1990 and 2016 (in thousand hides)

	1990	1995	2000	2005	2010	2015	2016
High	419	747	1,130	1,803	3,081	4,499	4,800
Low	201	358	541	864	1,476	2,156	2,300

These estimates assume that all of the production on the market is ejiao derived from donkey hides. Some sources suggest that up to 40 percent of ejiao is counterfeit (Xinhua News Agency, 2016). Our focus groups suggested that consumers are very aware of the problem of fake produce. Also at least one academic paper presents a new method to identify donkey hide gelatin from other species (Li *et al.*, 2017) and one paper that presents a method to identify DEEJ from other manufacturers (Li, 2016). This suggests that Chinese manufacturers are working on the problem of counterfeit production and that the number of hides used in production might be lower.

[1] Report on DEEJ on a Chinese platform http://www.sohu.com/a/129809208_135357

As to future demand, it is likely that the large manufacturers are working intensively on research to improve the efficiency of the production process and the size and quality of the hides. Dong'e Ejiao (DEEJ), a large producer of top quality ejiao, is said to have a breeding base in China that breed donkeys with hides twice as large as those of average donkeys. The future demand for donkeys for hides will be influenced not only by trends in the drivers for ejiao demand but also by the technological progress in breeding and in the production process.

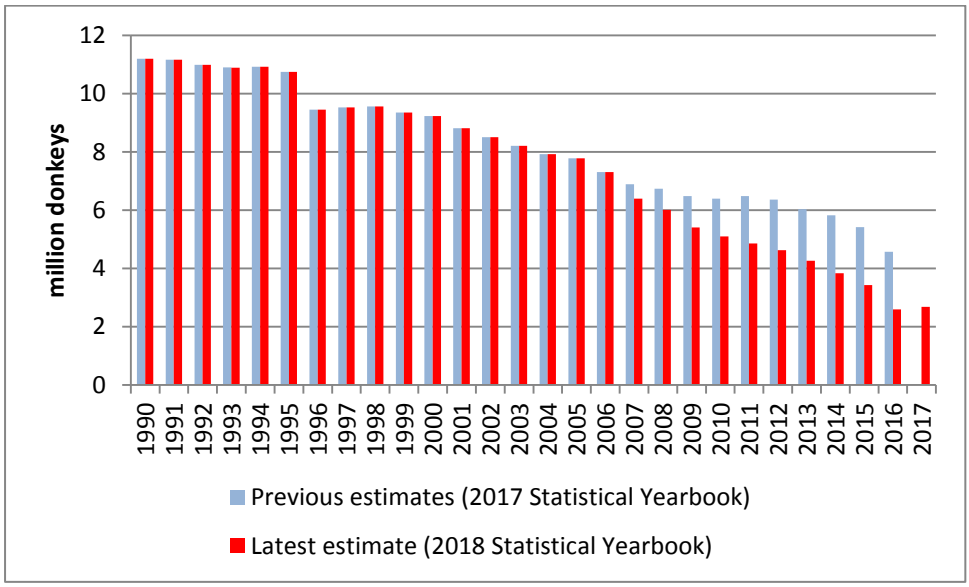
To summarise, a number of drivers have substantially increased the demand for ejiao over the last three decades. Demand for ejiao is likely to continue to increase.

3. Supply of donkey hides

Donkey population and donkey hide supply in China

While the demand for donkey hides has gone up significantly, the supply of donkeys in China has declined since 1990. According to official statistics by the National Bureau of Statistics of China the donkey population in China declined from 11.2 million in 1990 to 2.7 million in 2017. In the latest Statistical Yearbook, the estimates of the number of donkeys in China for the years 2007 to 2016 were substantially revised downwards. The number of donkeys in China in 2016 was previously estimated at 4.6 million and has been revised downwards to 2.6 million (see Figure 4). These revisions indicate that more donkey hides than previously assumed were available from the declining population over the last 10 years but also that the potential for future production is smaller than previously assumed. The estimate for 2017 suggests that the donkey population has stopped declining. The latest estimates show a small increase in the Chinese donkey population between 2016 and 2017. This is the first increase in the donkey population since 1998.

Figure 4: Donkey population in China from 1990 to 2017 (million head)



Source: China Statistical Yearbook 2017 and China Statistical Yearbook 2018

The main driver for the decline is the economic development of China over this period. Between 1990 and 2017, the number of mules, horses and donkeys declined by 85 percent, 66 percent and 76

percent, respectively. Over the same period, the number of number of small tractors more than doubled (from 7.0 million in 1990 to 16.3 million in 2017) and that of large and medium size tractors increased sevenfold (from 0.8 million to 6.7 million). (National Bureau of Statistics of China, 2018)

In January 2016 it was reported in Chinese newspapers that the Chinese supply of donkey hides is less than 1.8 million hides (Xinhua News Agency, 2016). Total Chinese supply of donkey hides is made up by the net decrease in the number of donkeys plus the number of births. The net change in the donkey population was 831 thousand. Hence, almost a million births would be required. This translates into 0.32 foals per donkey or roughly 0.65 foals per female donkey. No information is available on the number of donkey births in China but it seems unlikely that an average birth rate of 0.65 per female donkey has already been achieved.[2] Supply from Chinese donkeys was likely substantially below 1.8 million in 2016, leaving a large shortfall between Chinese supply and estimated demand of between 2.3 and 4.8 million donkey hides.

Future supply from China is likely to come mainly from donkey farming. It is clear that the Chinese farming programme has already started. There are reports that the President of DEEJ called for subsidies for donkey breeding already in 2010 (Swift, 2016). It is reported that in the last two years 15 provinces and 22 cities have announced their intention to provide donkey subsidies (Hancock and Xueqiao, 2018). A representative from DEEJ is said to have indicated that by 2020 DEEJ will be able to meet their basic needs for hides through their donkey farms (Hancock and Xueqiao, 2018). He also added that other companies will have to continue to rely on imports for another decade at least.

Donkey populations in the rest of the world and trade

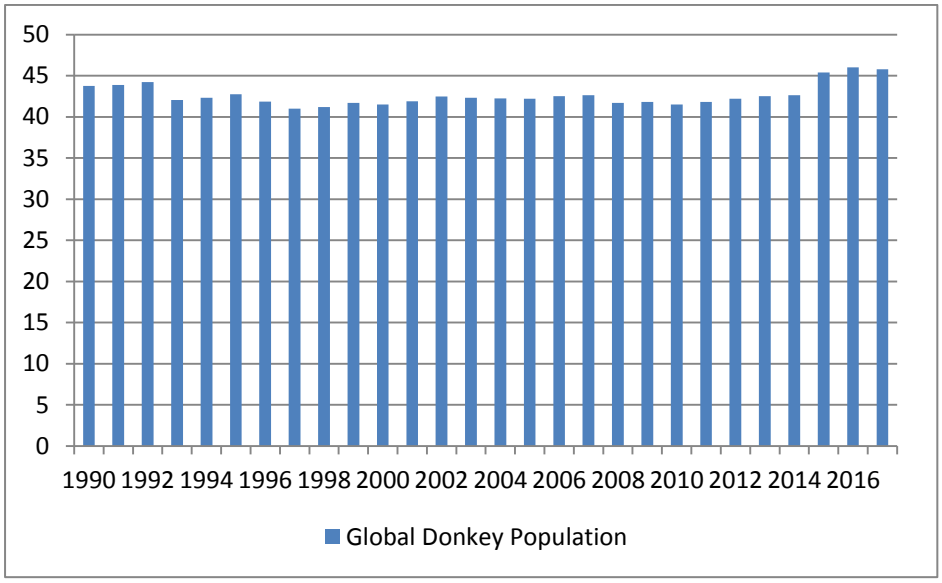
The world donkey population has been fairly stable over the last couple of decades according to estimates by the UN Food and Agriculture Organisation (FAO). Figure 5 shows estimates of the world donkey population since 1990. Over this period global donkey population was estimated at between 40 and 46 million.

This fairly stable global population masks marked differences between countries. China had by far the largest donkey population in 1990. In 2016 Ethiopia had the largest donkey population with more than 8 million donkeys. Ethiopia has seen a strong increasing trend in donkey population since 2000 with growth rates of between six and seven percent annually in the last three years for which data are available.

According to FAOSTAT there was an estimated donkey population outside China of 41 million. Using this figure a hypothetical supply of donkey hides from natural deaths can be calculated. It seems that the hides of most of these donkeys are not used upon their death. The best figures on population and deaths are figures from the Ethiopian survey. In 2016 the total donkey population was estimated at 8.4 million and deaths were estimated at 455,617 i.e. about 5 percent of the donkeys died in 2016. Using the same ratio for the total population outside China there would be a natural annual supply of donkey hides of 2.2 million.

[2] As a comparison, data from Ethiopia shows 0.075 foals per donkey and 0.15 foals per female donkey in Ethiopia.

Figure 5: Estimated global donkey population 1990 to 2017



Source: FAOStat

There are significant economic, cultural and governance barriers that mean that actual supply of donkey hides will be very much lower. Nevertheless, there is some potential for supply of donkey hides from existing populations through trade. In addition there is the potential for donkey farming in countries outside China which would increase the potential overall supply.

We obtained data on live donkey imports for 2012 and 2016, and on donkey hide imports in 2016. While the former is readily available, the latter is not as donkey hides are recorded in a category with hides from other species. No live donkey imports were recorded in 2012. In 2016 the official records show the import of live donkeys from Kyrgyzstan of around 1,600 live donkeys.[3] A report on imports of donkey hides in 2016 based on a detailed analysis of the other hides trade category suggests that about 100,000 donkey hides were imported, mainly from Mexico and Peru (together more than 90 percent of all imports).

These official trade figures are difficult to reconcile with both the gap in the estimated use of donkey hides and domestic supply in China and the suggestion that several million donkey hides are imported annual into China for ejiao production with many imported from Africa (Cong, 2018).

We conclude that there is currently a shortfall in supply of donkey hides that cannot be met either within China or from other countries. For this reason, counterfeit ejiao products and illegal activities are likely to have played and to continue to play an important role in the donkey hide and ejiao markets.

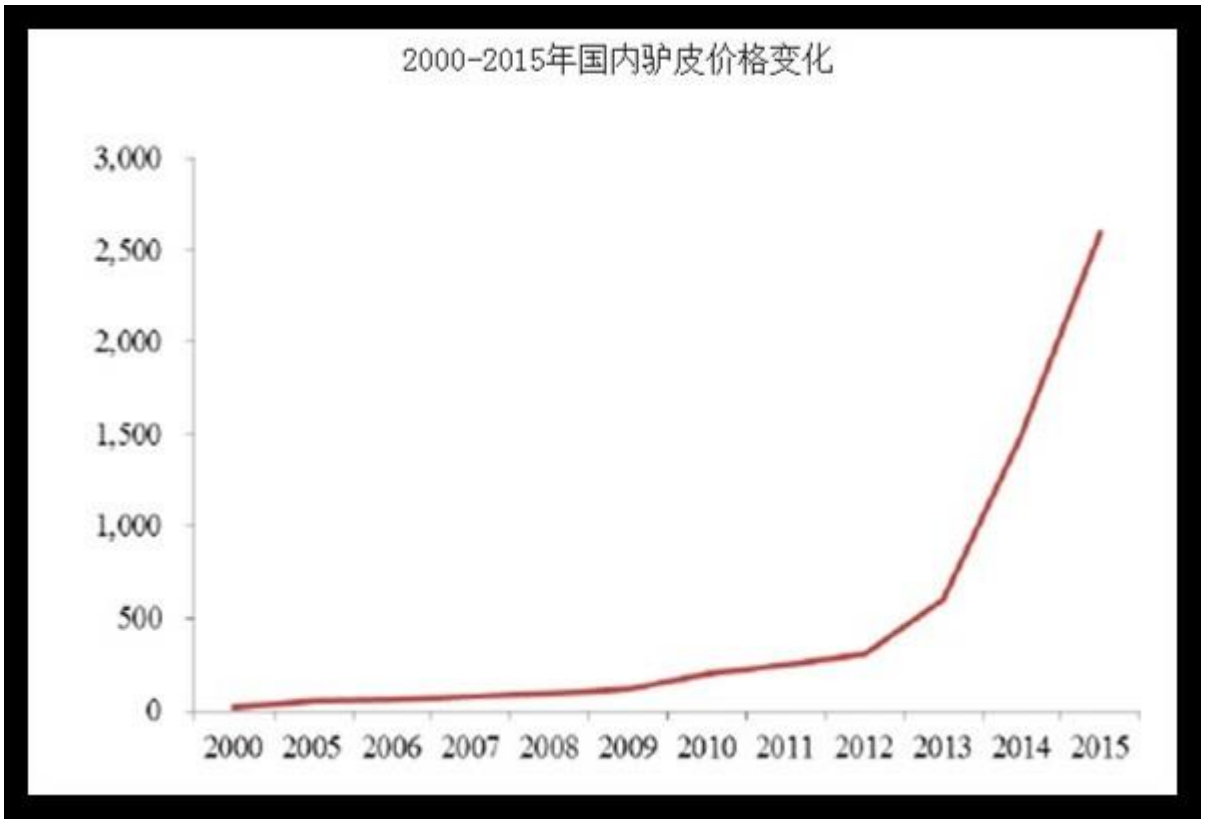
[3] The volume of imports is given as 320,417kg. If each donkey weighed around 200 kg this would translate into the import of about 1,600 donkeys.

4. Market impacts of the supply and demand trends

Our analysis suggests that while the supply of donkey hides in China exceeded the demand for donkey hides for ejiao production in the 1990. Over the last three decades demand for ejiao and donkey hides increased and supply of donkey hides decreased. There is currently a large shortfall of donkey hides in China that can only be partially met by imports. The supply and demand balance has led to sharp increases in the price of ejiao, of donkeys and of donkey hides. It is difficult to get reliable information on prices but indicative information is available from the grey literature and media reports. The overview below is not exhaustive but gives an indication of recent price movements.

Prices of donkeys and donkey hides have increased significantly over the last decade or so. Reliable price information could not be found. However, there are a number of prices reported in the media.

Figure 6: The price of donkey hides in China between 2000 and 2015



Source: Baolu and Jianing, 2016

Hancock and Xueqiao (2018) put the value of a donkey hide in 2018 at 3,000 yuan (USD 473) while other report an increase of a donkey hide from 20 yuan in 2000 to 3000 yuan end of 2017 (Xinhua News Agency, 2017). Bloomberg News (2017) report prices of donkey hides of up to 8,000 yuan (USD 1,160).

The price development suggests a tightening of the market from around 2009/2010 and a substantial shortage of supply from 2012 onwards, which is more in line with the low than the low

donkey hide usage scenario in section 2. The high donkey use scenario would suggest a shortage from the early 2000s.

The increase in the price of donkey hides has fed through into the ejiao price. One report suggests that the price of ejiao increased from about 500 yuan per 0.6 kg to 3000 yuan between 2009 and 2016 (Hancock and Xueqiao, 2018). Another source suggested a 5 times increase in the price in the decade between 2007 and 2017 reaching a price of 375 USD per kg in 2017 (Berhane, 2017).

The increase in the value of donkey hides in China has led to price increases of donkeys around the world. Table 3 shows a number of prices for donkeys reported in different media reports.

Table 3: Prices for donkeys reported in different media reports

Country	Price	Year	Source
Ethiopia	$90 to $150	2016	http://www.npr.org/sections/goatsandsoda/2016/11/07/500999944/donkeys-are-finally-getting-more-respect
Niger	$100 to $145	2016	http://www.bbc.co.uk/news/world-africa-37286811
Burkina Faso	£108 ($140)	2016	https://qz.com/925291/donkeys-in-kenya-are-slaughtered-to-meet-demand-for-ejiao-in-china/
South Africa	2 – 7k rand ($150 - $517)	2017	https://www.modernghana.com/news/763077/chinas-demand-for-medicine-fuels-african-donkey-slaughter.html
Nigeria	$150	2017	https://www.bloomberg.com/news/articles/2017-05-15/slaughter-of-africa-s-donkeys-for-china-hurts-poorest-farmers
Tajikistan	$240	2017	https://www.rferl.org/a/tajikistan-donkeys-hides-medicine-china/28486068.html

Reported prices in Africa, with the exception of the highest report from South Africa, are significantly lower than the current prices reported for donkey hides in China of between $473 and $1,160. The high end of the reported prices in most African countries is $150 – a third of the lower end of the prices quoted for China. This price differential is a strong economic incentive for trade.

5. Modelling supply of donkey hides in China and outside China

In order to help assess the potential supply of donkey hides two dynamic population models were developed using ISEE's Stella® Architect software. The first model was used to assess the potential of supplying donkey hides from setting up a donkey farming system. The second model assesses the potential for donkey skin supply from countries in which donkeys are primarily used for transport and where hides are a by-product that is currently not used.

The models give a broad indication of the global supply potential over time. Many of the parameters are very uncertain. Nevertheless, the model is a useful tool to get a better understanding of the issues and uncertainties involved in assessing the short and medium term potential to for the supply of donkey hides for ejiao production.

Model of a donkey farming system for hides

The first model is of a donkey farming system. The model assesses the time it takes to reach a specified sustainable annual supply of donkey hides. The model runs over 50 years. We assume that the farming population is started with only breeding animals. After one year the first foals are born. The majority of the male foals are slaughtered for their hide once they reach maturity. Maturity can be set at either 2 or 3 years. Thus, the first donkeys are slaughtered for their hides in year 3 or 4. The start of reproduction of female donkeys can be set at either 2 or 3 years. In the first years, no breeding animals are culled. This is based on the assumption that the starting breeding herd is made up of animals that are recruited into the breeding herd from elsewhere. It seems likely that these are young animals and not old animals towards the end of their reproductive age. All female donkeys enter the breeding herd until the target number of hides is reached. This minimizes the time needed to build up the population but reduces the number of hides available during the build-up of the population. Once the target number of hides is reached, females required to keep the breeding population stable are sent into the breeding herd, other female donkeys are slaughtered for hides at the age of maturity. The reproduction rate determines how many foals are produced from a given female breeding population. A reproduction rate of 0.7 means that 100 female donkeys produce 70 off-spring each year. Increases in the annual reproduction rate can be achieved in different ways: a decrease in time between pregnancies, increase in multiple births, shorter pregnancies (we understand there is some variation in the gestation period for donkeys), increase in pregnancies carried to term etc.

Mortality is included for under 1 year olds. The model assumes that the hides of donkeys that die under 1 are lost for hide production but that those dying between 1 and 2 can be used for hide production. The supply of the hides is made up of clean hides (from animals never used for breeding) and the hides of culled breeding animals.

Three example scenarios were developed. The parameters were informed by the information in the grey literature and through stakeholder consultation. All scenarios have a target hide output of 3 million donkey hides, which is close to the current lower end of the estimates of how many donkey hides are used for the production of ejiao. Table 4 shows the parameters used for these three scenarios.

Under scenario 1, the farming system can supply only 212 thousand hides after 50 years. To supply the 212 thousand hides a female breeding population of 854 thousand donkeys and a total donkey population within the farming system of 1.8 million donkeys is required. In this scenario the donkey population increases by five percent a year, which is less than the increases seen in Ethiopia over the last 5 years of almost 7 percent. In scenario 2 the target hide output of 3 million per year is reached after 34 years with a female breeding population of 6.9 million donkeys and a total donkey population of 14.5 million donkeys. Under the assumptions of scenario 2, it would take 20 years to get from a population of 2.5 million donkeys to the 14.5 million donkeys required for the annual supply of 3 million donkey hides. The total Chinese donkey population is currently estimated at 2.7 million donkeys but not all are part of donkey farms. Thus, under the assumptions of this scenario the Chinese farming system would need more than 2 decades to meet the 3 million target. Under scenario 3, it would take 20 years to achieve the target output of 3 million hides with 4.9 million female breeding donkeys and a total donkey population within the farming system of 12.1 million

donkeys. Under the assumptions of scenario 3, it takes 9 years to get from a total donkey population of 2.3 million donkeys to the 12.1 million donkeys that are required under scenario 3 to produce an annual output of 3 million donkey hides.

Table 4: Summary of assumptions for the three selected scenarios:

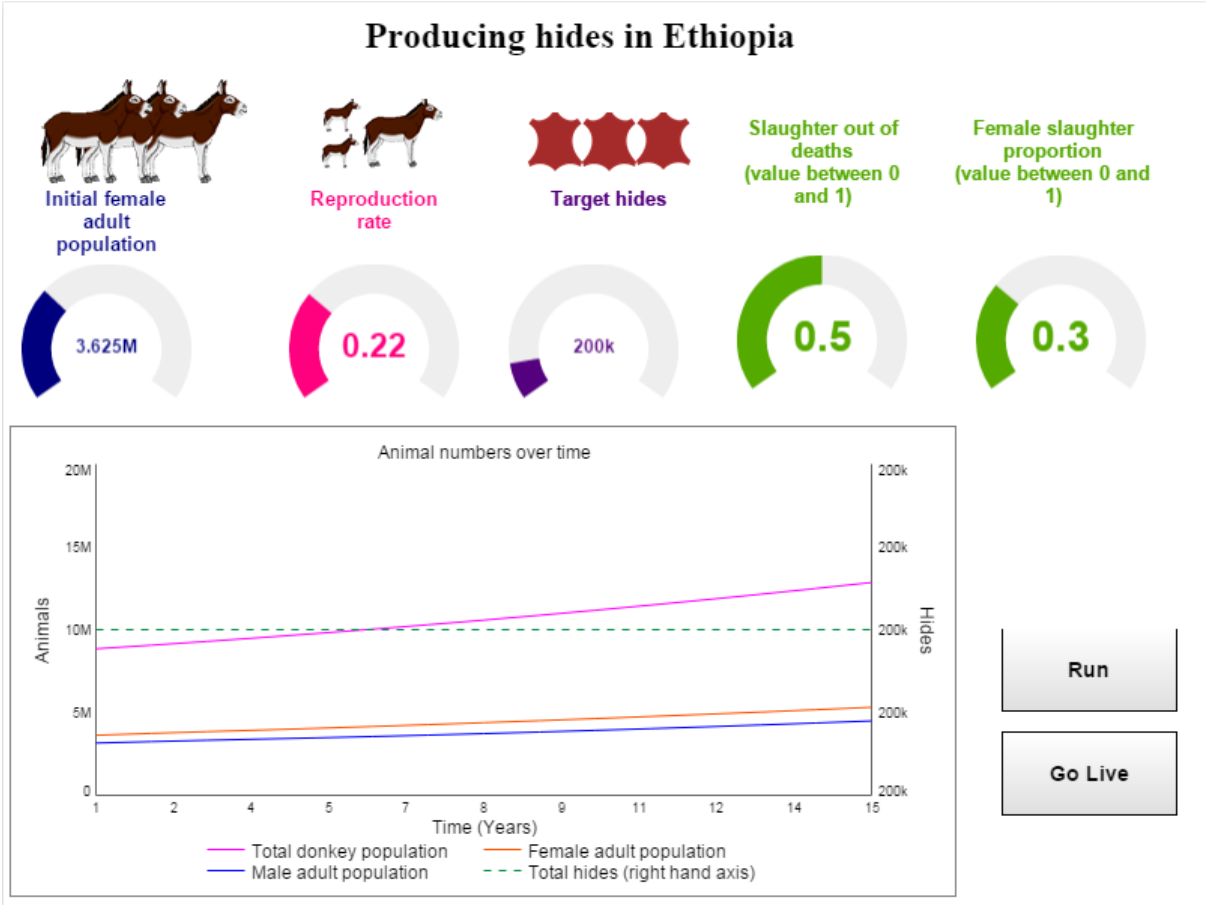
	Scenario 1	Scenario 2	Scenario 3
	Parameters		
Initial female breeding herd	50,000	100,000	200,000
Target hides	3 million	3 million	3 million
Reproduction rate (foal/jenny/year)	0.4	0.5	0.7
Female male breeding ratio	10	10	20
Female cull rate	10 percent	5 percent	5 percent
Maximum female breeding age	12 years	22 years	22 years
Male cull rate	10 percent	5 percent	5 percent
Maximum male breeding age	12 years	22 years	22 years
Mortality rate of under 1s	10 percent	5 percent	2.5 percent
Age at slaughter	3 years	2 years	2 years
Female maturity age	3 years	2 years	2 years
	Results		
Target hides reached in	-	34 years	20 years
Female breeding population year 50	0.9 million	6.9 million	4.9 million
Total donkey population year 50	1.8 million	14.3 million	12.1 million

These scenarios suggest that China is more than a decade away from supplying the donkey hides that are probably currently used in the production of ejiao.

Model of donkey hide supply from existing donkey populations

The second model is based on information from Ethiopia, the country with the largest donkey population. Not only has Ethiopia the largest donkey population, it also has detailed information on the donkey population. Based on this information we built a model that shows the theoretical supply capacity of such a population. In reality there are significant barriers to the supply of donkey hides from existing populations, for example the opposition to the slaughter of animals on cultural grounds, governance related problems, such as thefts as well as difficulties in accessing donkey populations (Addis Fortune, 2017; Masinde, 2017; The Donkey Sanctuary, 2017; Addis Standard, 2018; Nuwer, 2018; Brooke, 2019).

Figure 7 shows the interface of the model with results from Scenario 2.



The model starts with an existing donkey population. The donkey population is split into females under three years, males under three years, females three years and over and males three years and over. Total births depend on the adult female population and the reproduction ratio. The reproduction ratio is the average number of births per adult female donkey. The model splits the births into male and female births. Three years after birth, the donkeys move from the under 3 years population categories to the 3 years and over population categories. For simplicity, all deaths are assumed to be of adult donkeys as no split for the deaths by age groups is available. The slaughter flow is determined by the target hides specified. The model splits male and female slaughter and the ratio between male and female slaughter has to be set within the model. Due to the different requirements of females and males for breeding the split can have a noticeable impact on the population dynamics. Deaths are the second outflow from the model. Deaths record animals that die and whose hides are not used. The model allows the relationship between the deaths and slaughter to be specified. One extreme would be to assume that none of the donkeys that are slaughtered in one year would have otherwise died from natural causes in that year. the other extreme that all donkeys that are slaughtered would have died a natural death in that year. The reality will lie somewhere in between those two extremes. The number of animals slaughtered is an input into the model. The impact the number of slaughtered animals has on the natural deaths can be set within the model.

The model was parameterised with the results from the 2017/18 agricultural survey (Central Statistical Agency of the Federal Democratic Republic of Ethiopia, 2018). Table 5 summarises the parameters in the model that are based on the 2017/18 agricultural survey results.

Table 5: Parameter values based on the 2017/18 agricultural survey

	Parameter value
Initial adult female population	3,626,264
Initial adult male population	3,154,025
Initial female population under 3	1,027,342
Initial male population under 3	1,037,931
Total initial donkey population	8,845,562
Female birth proportion	0.52
Natural mortality rate	0.07
Reproduction rate (foals/jenny/year)	0.22

Table 6: Results from six scenario runs

	Scenario 1	**Scenario 2**	**Scenario 3**
	Parameters		
Female slaughter proportion	-	0.3	0.3
Proportion of donkeys slaughtered that would have died a natural death	-	0.5	0.5
Reproduction rate (foals/jenny/year)	0.22	0.22	0.22
Target hides	0	200,000	700,000
	Results		
Target hides sustainable over the 15 year period	-	Yes	Yes but with a small decrease in population
Total donkey population in 15 years	14.3 million	12.8 million	8.3 million
Female adult population in 15 years	5.7 million	5.3 million	4.3 million

	Scenario 4	**Scenario 5**	**Scenario 6**
	Parameters		
Female slaughter proportion	0.3	0.4	0.3
Proportion of donkeys slaughtered that would have died a natural death	0.5	0.8	0.1
Reproduction rate	0.22	0.28	0.22
Target hides	1,000,000	1,000,000	600,000
	Results		
Target hides supplied over the 15 year period	No	Yes	Yes but with a decrease in population
Total donkey population in 15 years	5.8 million	9.3 million	6.7 million
Female adult population in 15 years	3.7 million	4.7 million	3.5 million

The model runs over 15 years. The scenarios assess under which conditions the 2017/18 population could sustain a regular annual supply of donkey hides for ejiao production. Scenario 1 is the baseline scenario. It is based on the 2017/18 information from the agricultural survey on the donkey population in Ethiopia, donkey births and deaths. If the birth and mortality rate stayed the same over the next 15 years, without any slaughter of donkeys for ejiao, the donkey population in Ethiopia would increase from 8.8 million donkeys to 14.3 million donkeys, of which 5.7 million donkeys would be adult female donkeys. Scenario 2 assumes that 30 percent of donkeys slaughtered for their hide are female and 70 percent male and that 50 percent of those slaughtered for their hides would have died a natural death. Thus, it is assumed that half of the donkeys used for hides are old, weak or ill but that the other 50 percent slaughtered are healthy donkeys. The reproduction rate is set at the 2017/18 level. Under these assumptions, the donkey population would increase over the 15 year period from 8.8 million at the start to 12.8 million after 15 years. Scenario 3 has the same assumptions as Scenario 2 with the exception that the target for the annual supply of donkey hides is 700,000. In this scenario 700,000 can be supplied over the period but the donkey population would show a decline from 8.8 million to 8.3 million. Scenario 4 is as scenario 3 but with an annual supply of donkey hides of 1 million hides. In this scenario, for the first 10 years 1 million hides are supplied but partly to a reduction in the donkey population. For the last 5 years, the 1 million target is not reached any more. Scenario 5 shows the conditions under which 1 million hides could be supplied while keeping the donkey population marginally increasing from 8.8 million to 9.3 million. It would require an increase in the reproduction rate from 0.22 to 2.8, making use of 80 percent of the donkeys that would die in each year for the hide supply as well as a higher percentage of females to be slaughtered. Scenario 6 shows that if most of the donkeys slaughtered are healthy donkeys, that is if 10 percent the old and weak donkeys that die are used for their hides an annual supply of 600,000 donkeys would only be possible at the expense of a reduction in the donkey population.

6. Discussion and conclusion

We provide an assessment of past, current and future developments of the supply and demand of donkey hides for ejiao production. Over the last three decades the annual demand for donkey skins has probably increased more than tenfold. We estimate that in 1990 at most 400,000 donkey hides were used for ejiao production. Since then demand for donkey skins for ejiao has increased rapidly. We estimate that currently between 2 and 5 million donkey skins are necessary annual for the production of ejiao. Economic development has made ejiao affordable for a much larger section of the Chinese population and it is now one of the most widely used products in Traditional Chinese Medicine. Over the last few years, the Chinese government has put policies in place to increase the use of Traditional Chinese Medicine, leading to a further increase in demand for ejiao. We conclude, therefore, that overall demand for ejiao is likely to continue to increase. These broad trends are likely to continue. As a consequence, the demand for ejiao is likely to continue to increase in the foreseeable future.

Information on the donkey population and donkey hide prices indicates that from around 2009/2010 domestic supply could not meet the demand for donkey hides any more. Several sources suggest that annual imports of several hundreds of thousand, if not millions of donkey hides have been imported annually in recent years (Cong, 2018; Hancock and Xueqiao, 2018). Official data on imports

does record donkey hides in a separate category. A report based on official customs data record much lower imports. There are a number of possible reasons for this discrepancy. Firstly, the data from official customs records is only based on one trade code. Though we were advised that donkey hides are recorded under this trade code, we cannot exclude the possibility that some trade is recorded under other trade codes. Secondly, donkey hides might be imported illegally and/or misclassified as hides from other animals. Thirdly, it is possible that the estimates of imports are based on estimates of use of hides in the ejiao industry and the availability of hides from China. Such an analysis indicates a large import requirement. The information on the number of hides required in ejiao production might be unreliable. Little information is available about the production process but also about the variation in the size of hides. A DEEJ representative claims that they are breeding donkeys double the size of ordinary donkeys which would reduce the number of hides required. In addition, the supply of donkeys is subject to uncertainty. In 2018, the National Bureau of Statistics of China revised its estimates of the donkey population in recent years downwards. Between 2007 and 2016, the donkey populatio in China decreased more rapidly than previously thought. This means that the hides of more donkeys than previously thought could have been used for ejiao production over this period. It also suggests a lower production capacity in China in the near future than previously thought. Fourthly, it is possible that a substantial proportion of the ejiao on the Chinese market is fake and either does not contain any donkey gelatin or that donkey gelatin is used together with gelatin from other species, either related species such as mules and horses or from other species such as pigs.

Our model of a donkey farming system indicates that it will take at least another decade until China can produce 3 million donkey hides annually, which is less than some estimates for the current use in ejiao production. Donkey populations around the world are a possible source of donkey hides for the ejiao industry. Our model shows that a population of the size and the characteristics of the Ethiopian donkey population could in theory supply several hundred thousand hides a year without decimating the population even without an increase in the reproduction rate. With an increase in the reproduction rate, the theoretical capacity could approach 1 million hides a year. However, in reality there are a number of barriers to reach this theoretical capacity, such as the lack of infrastructure and trading routes, cultural barriers and governance issues.

To conclude, rapidly increasing demand for ejiao and a decrease in supply of donkey hides within China have led to strong import demand for donkey hides. We expect the increasing trend in demand to continue. There is evidence that a donkey farming system was started in China several years ago. The most recent estimates of the donkey population in China suggest that the reduction in the Chinese donkey population has come to an end with a small increase in the donkey population in the last year. However, based on the current estimate of the Chinese donkey population of 2.7 million donkeys, it seems unlikely that China will be able to meet the demand for donkey hides from domestic supply for at least another decade, if not two. Imports are unlikely to close the gap between demand and supply. As a consequence, the prices of ejiao and of donkey hides are likely to increase further over the next few years. This is likely to further incentivize legal and illegal activities in relation to donkeys and donkey hides all over the globe and to put even greater pressure on donkey populations.

References

Addis Fortune (2017) *Ethiopia: First donkey abattoir shuts down*, *Tesfanews*. Available at: https://www.tesfanews.net/ethiopia-first-donkey-abattoir-shuts-down/.

Addis Standard (2018) 'Newa: The Donkey Sanctuary and Ethiopian Government commit to safeguarding national donkey herd', *Addis Standard*, 28 November. Available at: http://addisstandard.com/news-the-donkey-sanctuary-and-ethiopian-government-commit-to-safeguarding-national-donkey-herd/.

Baolu, Y. and Jianing, N. (2016) 'The depth of the investigation, the outlet on the donkey', *Best China News*, 16 December. Available at: http://www.bestchinanews.com/Domestic/11652.html.

Berhane, S. (2017) 'Donkey Meat Up for Export, Slaughterhouse Opens', *Addis Fortune*, 1 April. Available at: https://addisfortune.net/articles/donkey-meat-up-for-export-slaughterhouse-opens/.

Bloomberg News (2017) 'Have a Donkey to Trade? China Has an Exchange for That', *Bloomberg Businessweek*, 29 March. Available at: https://www.bloomberg.com/news/articles/2017-03-29/china-has-exchange-traded-donkeys.

Brooke (2019) *Demand for Africa's donkeys causing terrible suffering*, *Brook*. Available at: https://www.thebrooke.org/news/demand-africas-donkeys-causing-terrible-suffering (Accessed: 14 March 2019).

Butler, S. (2015) 'Amid Pollution Problems, China's Health Food Industry Blossoms', *Huffington Post*, 27 March. Available at: https://www.huffingtonpost.com/2015/03/27/china-health-food_n_6958390.html.

Central Statistical Agency of the Federal Democratic Republic of Ethiopia (2018) *Report on Livestock and Livestock Characteristics, Volume II, Agricultural Sample Survey 2017/18*. 571. Addis Ababa.

Chen, Y., Zhang, G., Chen, X., Jiang, X., Bie, F., Yuan, N., Wang, Y., Hao, X. and Ma, M. (2018) 'Jianpi Bushen , a Traditional Chinese Medicine Therapy , Combined with Chemotherapy for Gastric Cancer Treatment : A Meta-Analysis of Randomized Controlled Trials', 2018.

Chinese Herbs Healing (no date) *E Jiao (Colla Corii Asini, Donkey-Hide Gelatin)*, *Chinese Herbs Healting - Art of Herbal Remedies Revealed*.

Chu, N., Wu, Z., Zhang, X., Fang, S., Wang, W. and Cheng, Y. (2014) 'Molecular Mechanism of Yisui Shengxue Granule , a Complex Chinese Medicine , on Thalassemia Patients Suffering from Hemolysis and Anemia of Erythrocytes', 2014.

Chung, V. C. H., Ma, P. H. X., Wang, H. H. X., Wang, J. J., Hong, L. C., Wei, X., Wong, S. Y. S., Tang, J. L. and Griffiths, S. M. (2013) 'Integrating Traditional Chinese Medicine Services in Community Health Centers: Insights into Utilization Patterns in the Pearl River Region of China', *Evidence-Based Complementary and Alternative Medicine*, 2013, pp. 1–8. doi: 10.1155/2013/426360.

Cong, W. (2018) 'Nation hunts self-sufficieny in donkey hide', *Global Times China*, 2 January. Available at: http://www.globaltimes.cn/content/1083014.shtml.

Customs Information Network (2017) *2016 Annual Donkey Skin Import Analysis Report*.

Fang, H. (no date) *The Chinese Health Care System*, *International Health Care System Profiles, The Commonwealth Fund*. Available at: https://international.commonwealthfund.org/countries/china/.

Farag, M., NandaKumar, A. K., Wallack, S., Hodgkin, D., Gaumer, G. and Erbil, C. (2012) 'The income

elasticity of health care spending in developing and developed countries', *International Journal of Health Care Finance and Economics*, 12(2), pp. 145–162. doi: 10.1007/s10754-012-9108-z.

Ge, S., He, T. T. and Hu, H. (2014) 'Popularity and customer preferences for over-the-counter Chinese medicines perceived by community pharmacists in Shanghai and Guangzhou: A questionnaire survey study', *Chinese Medicine (United Kingdom)*, 9(1), pp. 1–8. doi: 10.1186/1749-8546-9-22.

Han, J., Zhao, Q. and Zhang, M. (2016) 'China's income inequality in the global context', *Perspectives in Science*. Elsevier GmbH, 7, pp. 24–29. doi: 10.1016/j.pisc.2015.11.006.

Hancock, T. and Xueqiao, W. (2018) 'China bets on donkey breeding to curb Africa imports', *Financial Times Online*, 15 February. Available at: https://www.ft.com/content/bee2b852-0190-11e8-9650-9c0ad2d7c5b5.

KPMG (2016) 'The 13th Five-Year Plan – China ' s transformation and integration with the world economy', *Kpmg*, (October). Available at: https://assets.kpmg.com/content/dam/kpmg/cn/pdf/en/2016/10/13fyp-opportunities-analysis-for-chinese-and-foreign-businesses.pdf.

Law of the People's Republic of China on Traditional Chinese Medicine (2017). Available at: http://en.pkulaw.cn/display.aspx?cgid=287286&lib=law.

Li, L., Leung, P. C., Chung, T. K. H. and Wang, C. C. (2014) 'Systematic review of Chinese Medicine for miscarriage during early pregnancy', *Evidence-based Complementary and Alternative Medicine*, 2014. doi: 10.1155/2014/753856.

Li, W. (2016) 'Manufacturer identification and storage time determination of "Dong'e Ejiao" using near infrared spectroscopy and chemometrics', *Journal of Zhejiang University-SCIENCE B*, 17(5), pp. 382–390. doi: 10.1631/jzus.B1500186.

Li, X., Shi, F., Gong, L., Hang, B., Li, D. and Chi, L. (2017) 'Species-specific identification of collagen components in Colla corii asini using a nano-liquid chromatography tandem mass spectrometry proteomics approach', *International Journal of Nanomedicine*, 12, pp. 4443–4454. doi: 10.2147/IJN.S136819.

Masinde, J. (2017) *As other African countries ban donkey slaughter, Kenya doubles down to meet Chinese demand*, *Quartz Africa*. Available at: https://qz.com/africa/1062794/as-other-african-countries-ban-donkey-slaughter-kenya-doubles-down-to-meet-chinese-demand/.

National Bureau of Statistics of China (2018) *China Statistical Yearbook 2018*. Available at: http://www.stats.gov.cn/tjsj/ndsj/2018/indexeh.htm (Accessed: 8 March 2019).

Nofri, E. M. (2015) *The Chinese Healthcare System: How it works and future trends*. Available at: http://www.albertoforchielli.com/the-chinese-healthcare-system-how-it-works-and-future-trends/ (Accessed: 1 March 2019).

Nuwer, R. (2018) 'To Sate China's Demand, African Donkeys Are Stolen and Skinned', *The New York times*, 2 January. Available at: https://www.nytimes.com/2018/01/02/science/donkeys-africa-china-ejiao.html (Accessed: 14 March 2019).

OECD (2017) 'OECD Economic Surveys: China', (March). Available at: http://www.oecd.org/eco/surveys/china-2017-OECD-economic-survey-overview.pdf.

Swift, A. (2016) *Ejiao: Donkeys are paying the price for China's rapid progress and lost traditions*.

Available at: https://donkeytime.org/2016/12/18/ejiao-donkeys-are-paying-the-price-for-rapid-progress-and-lost-traditions/ (Accessed: 3 March 2019).

The Donkey Sanctuary (2017) *Under the skin: The emerging trade in donkey skins and its implications for donkey welfare and livelihoods*. Sidmouth. Available at: https://www.thedonkeysanctuary.org.uk/sites/uk/files/2017-11/under_the_skin_report.pdf.

Wang, D., Liu, M., Cao, J., Cheng, Y., Zhuo, C., Xu, H., Tian, S., Zhang, Y., Zhang, J. and Wang, F. (2012) 'Effect of Colla corii asini (Ejiao) on D-Galactose Induced Aging Mice', *Biological and Pharmaceutical Bulletin*, 35(12), pp. 2128–2132. doi: 10.1248/bpb.b12-00238.

World Bank (2019) *World Bank National Accounts Data*, *DataBank*. Available at: https://data.worldbank.org/indicator/NY.GDP.PCAP.KN?locations=CN (Accessed: 8 March 2019).

Xinhua News Agency (2016) 'Shortage of donkey skin breeds TCM fakes', *China Daily*, 28 January. Available at: http://www.chinadaily.com.cn/china/2016-01/28/content_23287841.htm.

Xinhua News Agency (2017) 'China cuts tariff on donkey hides', *CGTN*, 31 December. Available at: https://news.cgtn.com/news/3067444d35637a6333566d54/share_p.html (Accessed: 13 March 2019).

Yang, F., Song, J., Liang, M., Ma, F., Mao, X., Ma, C. W., Zhang, W. and Huang, Z. (2014) 'Overview of Beverages with Anti-Aging Functions in Chinese Market.', *Rejuvenation research*, 17(2), pp. 1–4. doi: 10.1089/rej.2013.1514.

Yang, H., Yang, J., Wen, Z., Zha, Q., Nie, G., Huang, X., Zhang, C., Lu, A., Jiang, M. and Wang, X. (2012) 'Effect of combining therapy with traditional chinese medicine-based psychotherapy and herbal medicines in women with menopausal syndrome: A randomized controlled clinical trial', *Evidence-based Complementary and Alternative Medicine*, 2012. doi: 10.1155/2012/354145.

Yin and Yang House (no date) *Yin Yang House Theory - Explore Acupuncture and Herbal Medicine- E Jiao*. Available at: https://theory.yinyanghouse.com/theory/herbalmedicine/e_jiao_tcm_herbal_database (Accessed: 13 March 2018).