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Skies without limits

Drones – taking the UK’s economy to new heights



#IntelligentDigital

Drones are becoming an increasingly familiar aspect of life and work in the UK today, playing a growing role in areas ranging from emergency services to construction to oil and gas. But this is just the start.



Contents

- 2 Poised for take-off
- 6 UK 2030: the economic impact
- 10 Boosting productivity – £16bn in net cost savings
- 12 Using technology for good
- 14 628,000 people in the drones economy
- 16 Over 76,000 drones in the UK skies
- 18 Turning potential into reality
- 20 Appendix: Defining drones
- 26 Contacts



Poised for take-off

Drones are becoming an increasingly familiar aspect of life and work in the UK today, playing a growing role in areas ranging from emergency services to construction to oil and gas. But this is just the start.

During a time when organisations are under pressure to be more efficient, innovative and ambitious in how they deliver services, drones offer a unique lens on the world below. Gathering data quickly and accurately from hard to reach places, they can create a 'golden record' in near real time. This can make a crucial difference in **managing costs, controlling risks, increasing safety and influencing outcomes**.

This study outlines the financial, employment, productivity and quality of life impact that drones will have on the UK economy and provides examples of current and future commercial drone applications.

The rising use of drones in business and public services will be highly impactful and deliver significant benefits for the UK economy and society. **Our study into the impact of drones shows that, by 2030, there could be:**

£42bn

increase in UK gross domestic product (GDP)

£16bn

in net cost savings to the UK economy

76,000

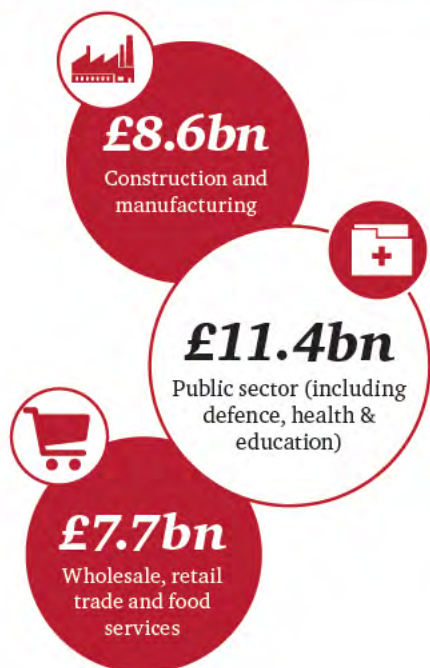
drones operating in the UK's skies

628,000

jobs in the drones economy



GDP uplifts across industries



The level of cost savings will vary between industries, with the UK's technology, media and telecoms (TMT) sector reaping the biggest cost reductions, at some £4.8bn by 2030. Other sectors including financial services, transport and logistics, and government services also have great potential to see major savings.

These savings will, in turn, help the UK economy address one of its major long-term challenges: productivity. Cost reductions and efficiency improvements from drone usage will feed into an increase of 3.2% in 'multi-factor' productivity across the UK economy, and contribute to considerable GDP uplifts in many industries. These include: £8.6bn in construction and manufacturing; £7.7bn in wholesale, retail trade and food services; and £11.4bn in the public sector (including defence, health & education).

The impact on jobs will be substantial due to the combination of drones and automation. Over time the gains generated by drones in cost savings, productivity and consumer demand will transform how we work and live and create significant new employment opportunities for those that are willing to retrain.

Taken together, these positive impacts will result in explosive growth in the number of drones in UK airspace. Of the 76,000 drones that we project will be flying across UK skies by 2030, over a third (36%) will be used by the public sector, contributing to a safer UK and enabling these sectors to embrace the other myriad benefits of digital transformation that drones enable.

A convergence of technology, societal acceptance and regulation

We predict that, over the next decade, the UK will see a convergence of technology, societal acceptance and regulation which will unlock the full economic potential of drones.

Technology

As the technological capabilities of drones and related software continue to develop, the associated benefits and commercial applications will continue to expand. The use cases mentioned in this report are just a small sample of the benefits drones can deliver, and as drone and sensor technology continues to evolve so will their uses for both business and society as a whole.

Societal acceptance

The overall impact of drones on our economy and society is likely to be broader and deeper than the economic figures suggest. In PwC's *Innovation for the Earth* work, we explore how many of the emerging *Fourth Industrial Revolution* technologies, including autonomous vehicles and drones, can accelerate innovative solutions to help address some of the world's most pressing environmental challenges. Drones are highly effective in environmental monitoring; for example, by tracking ice flow and whale movement in the Arctic or even collecting whale spray for analysis.

As drones become more commonplace, businesses and public services will need to use drones responsibly and ethically to allay public concerns over safety, privacy and misuse, particularly as drones become autonomous. By embracing *Technology for Good* the drones industry will help make an important contribution to the UK's sustainable development over coming years and decades, and so we will see a shift in societal perception of drones to be a technology that delivers positive social, environmental and financial outcomes.

Regulation

For the projections in this report to be realised, the current regulations must evolve to allow further drone use cases. Drones differ from other emerging technologies such as artificial intelligence (AI) in that the government is responsible for the safety of its airspace, so all uses of drones will need to comply with regulation to ensure airspace safety. Other limitations related to flying in congested areas and collecting personal data, for example by flying near buildings and people or over roads, also need to be considered.

The UK Government is committed to remaining at the forefront of the global drones market so that the economic potential can be realised whilst prioritising the *safety and security* of UK citizens. Trials are already being run with the aim of proving 'beyond visual line of sight' (BVLOS) flying is possible while protecting people and property.

Given the momentous benefits, UK organisations across a range of industries are watching advances in drone technology with keen interest, and asking many questions about the implications for their business. We hope this report will help to stimulate this thinking.

Flying cars – a vision of the future

Although driverless, autonomous flying cars are still in early development, the capabilities are swiftly maturing. Successful trials have already been conducted of passenger-carrying drones and applications include driverless air taxis. There are also plans to deploy hybrid driverless cars that can operate as both road and aerial vehicles, with the road or aerial functionality being selected to optimise journey time and/or limit the environmental impact. However, a number of technological, ethical and regulatory challenges must be addressed before air taxis can be turned from a concept into a reality.

Key questions to ask...

- What impact could drones have on our organisation?
- Which drone capabilities will give us a competitive edge as a business?
- Does our business model position us as a drone-enabled disrupter?
- To seize the opportunity where should we target our investment?



UK 2030: the economic impact

A £42bn uplift in GDP

Drones are a game-changer for the UK economy. Companies that embrace the nascent drone technology can transform their business performance, unlock significant value and reduce risk. Our projection for the impact drones can have by 2030 is a GDP uplift of £42bn against our baseline forecast, or more than 1.89% of GDP.

We expect the adoption of drones in the UK to follow an ‘S-curve’ pattern similar to previous waves of new technology. Our view of the future uptake and GDP benefits from drones is also aligned with PwC’s recent global study of the commercial applications of drones *‘Clarity from Above’*.

We’re projecting the net effect of drones on GDP – not GDP itself

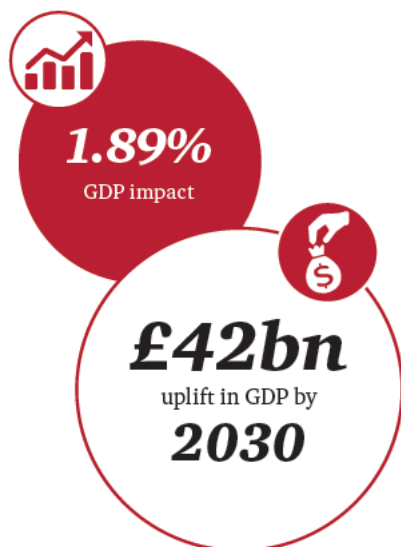
It’s important to stress that our GDP projection shows the potential ‘size of the economic prize’ from drones for the UK, not the rate of overall GDP growth itself. Our analysis indicates there will be an additional 1.89% GDP growth from drones, and this uplift may be on top of our baseline forecast, or part of it, since we can’t be sure whether drones will provide additional growth on top of typical technology driven productivity gains that comprise the baseline forecast. The £42bn forecast holds true either way.

Our GDP figure takes account of the creation and destruction of some activities, and the shifting of others between sectors. In this context, our GDP forecast figure is ‘net’ and in line with the UK Government’s appraisal guidance, *HM Treasury’s ‘Green Book’*.

We conducted our analysis of the economic impact of drones in three phases

- Phase 1 – Estimating the net cost savings from drones in the UK. We drew on PwC’s previous *‘Clarity from Above’* report to estimate the UK’s gross cost savings from drone usage, and then used external data and expert PwC analysis to estimate the net cost saving per UK sector.
- Phase 2 – Estimating the productivity increases in the UK. We merged our estimate of the net cost savings with data on the total cost of capital and employment per UK sector to calculate the increase in productivity by sector.
- Phase 3 – Projecting the total economic impact of drones. We input our multi-factor productivity figures into our Computable General Equilibrium (CGE) model to work out the aggregate effects of drones uptake on UK GDP up to 2030, and the total number of jobs impacted by drones as a result.

A more detailed description of our methodology, including the S-curve pattern we expect GDP to follow, is provided in the Appendix.





Reducing costs and risk in oil and gas


Drones have seen significant uptake in the oil and gas industry. They improve safety, increase efficiency and deliver significant cost savings. Drones have dramatically reduced employee exposure to 'working at height' (the number two cause of *industrial fatalities* in UK in 2017) and to other hazardous environments such as the inside of storage tanks.

Combined with traditional techniques, drones can dramatically increase the efficiency of inspection. For an underdeck inspection on an oil platform, a drone can complete in five days what would take eight weeks with a traditional scaffolding approach. Rope access crews only then need attend to the defective areas identified by the drone inspection.

The ability of drones to inspect while an asset is 'live' delivers noteworthy cost avoidance. Inspecting a live flare stack can save £4m+ per day compared to shutting the asset down for traditional inspection.

Other applications include pipeline inspection, gas sensing, oil spill monitoring, delivery, environmental/wildlife monitoring and security. The next steps are for drones to become autonomous and mirror the development of subsea drones (remotely operated vehicle or ROV) to, for example, use mechanical arms to take wall thickness readings at an area of corrosion.

Unlike remotely operated vehicle (ROV) developments of the last decades, drone developments are taking place at a time when we are moving towards the Fourth Industrial Revolution. What could emerge is a convergence of technologies where each oil and gas facility has a compliment of aerial, ground and subsea robotics that autonomously inspect and repair based on deviations that robotic or other Internet of Things (IoT) sensors identify against the baseline digital model held by the facilities AI.

An aerial photograph of a high-voltage powerline tower in a lush green field. The tower is a complex lattice structure made of metal, with several powerlines extending from it across the landscape. The field is divided into rectangular plots, and a dirt path is visible in the lower right. The sky is not visible, as the image is dominated by the greenery and the tower.

Utilities

Drone use is well established in the utility industry, in particular for the inspection of long, linear assets such as powerlines and 360 degree visualisation of critical infrastructure including sub-stations and hydro dams.

Sophisticated cloud-based visual asset management systems are emerging. Acting as repositories for inspection information from drones, helicopter and ground patrol, seamless links to the Enterprise Resource Planning (ERP) systems can then generate repair works orders for a component defect. This can increase the quality of the inspection information, enhance collaboration, improve decision making (especially prioritisation of repair resources) and demonstrate clear control of critical assets.

In the land survey field, recent advances in payloads and BVLOS flying is likely to result in drones replacing more expensive helicopters in many applications. Combined with the use of sophisticated algorithms that use point cloud data from laser scanning to precisely calculate critical '3D' parameters, such as vegetation encroachment and conductor sag height on powerlines, the impact of technology convergence will be significant.

GDP impact by sector

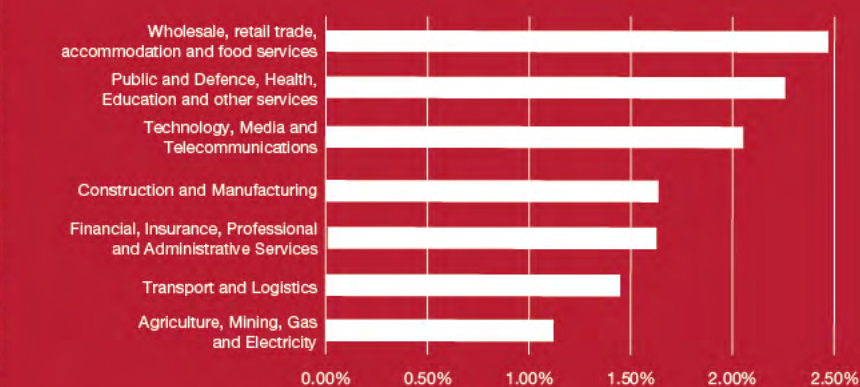
Figure 1 breaks down, by sector, what we believe the GDP uplift from drones uptake will be by 2030. While the chart shows the percentage GDP that drones will add against our baseline forecast, the absolute increase in financial terms will depend on each sector's size. Taking this into account, we estimate that using drones will result in construction and manufacturing seeing a GDP uplift of £8.6bn; wholesale, retail trade and food services an uplift of £7.7bn; and public sector (including defence, health & education) an uplift of £11.4bn.

The benefits will arise in different ways in different sectors. Wholesale and retail trade will see the largest GDP impact in percentage terms because it makes heavy use of inputs

from the transport and logistics industry which will see high savings and productivity impacts from drones. Similarly, the big uplift for public sector will result from reduced input costs from other services directly impacted by drones.

Conversely, agriculture, mining, gas and electricity will see a lower GDP increase as a result of drone adoption, because demand for its products may not rise by very much: people need only a fixed amount of water, energy, and other utilities. Here, it is important to note that relevant applications such as drone-based network monitoring, maintenance and plant repair are captured elsewhere in construction and manufacturing.

Figure 1: Sector GDP impact of drones in the UK in 2030 (%)



Boosting productivity – £16bn in net cost savings

For all industries in the UK, the most immediate economic impact from drones will come from lower costs and improved productivity. Using drones to automate routine tasks will also enhance safety performance, reduce risk, improve quality and free people up to focus on more interesting and value-adding work. It follows that the sectors that will enjoy the largest productivity gains from drones will be those with a high proportion of operational processes that can be automated and/or involve physical movement of goods or people.

Our analysis suggests that the UK as a whole is set to reap total net cost savings of up to £16bn from the uptake of drones, resulting in an overall increase of 3.2% in ‘multi-factor’ productivity. This finding is set out in Table 1, along with our estimates for the cost savings and productivity gains by sector.

A further consideration is that some uses of drones affect more than one sector, spreading the productivity gains across industry boundaries. The direct productivity will also substantially impact of using drones for infrastructure maintenance is captured in the construction and manufacturing sector, but will substantially benefit the oil, gas and electricity industries by minimising power outages through proactive monitoring.

Delivery drones – a vision for the future

Delivery drones could become business as usual by 2030. Large retail and logistics companies are investing in delivery drones with the aim of achieving increased efficiency, lower costs, and increased customer satisfaction. The scope of delivery drones could also be beyond dropping off parcels in the ‘last mile’ of client logistics. Drones will be ubiquitous in warehousing and able to autonomously conduct real time stock checks by scanning inventory. This will integrate seamlessly with other ground-based autonomous warehouse robotics in an end-to-end management and movement of inventory driven by AI with no human touch.

Delivery drones could also integrate with other advances in technology, for example a driverless vehicle, loaded with parcels by robotics at the warehouse that automatically dispatches multiple delivery drones when it nears the most efficient point to complete its deliveries. Such a vehicle would serve as a base station for the drones providing charging and payload swapping as required. This scenario is some way off, as current technical and regulatory challenges remain such as flying pilotless and beyond visual line of site (BVLOS) in congested urban areas and integrating with other airspace users.

Productivity impacts by sector

As Table 1 shows, the technology, media and telecommunications (TMT) sector and transport and logistics sector will see the biggest productivity gains. This reflects these two industries' substantial opportunities to cut costs using drones and their relatively small size compared to other sectors. In contrast, the productivity impact of drones on the public sector will be muted by its very large size, incorporating defence, education, health, and more.

Meanwhile, the effect on the retail and wholesale trade sector will be held back by the fact that the direct benefits fall within the transport and logistics sector.

Table 1: Gross and net cost savings, and multi-factor productivity impact by 2030, by UK sector

Sector	Gross cost saving from drones uptake	Net cost saving from drones uptake	Multi-factor productivity impact by 2030
UK wide	£17bn	£16bn	3.2%
Technology, Media and Telecommunications	£4.9bn	£4.8bn	12.4%
Financial, Insurance, Professional and Administrative Services	£4.1bn	£4.1bn	2.8%
Construction and Manufacturing	£3.5bn	£3.5bn	3.1%
Transport and Logistics	£2.8bn	£2.8bn	8.4%
Public and Defence, Health, Education and other services ¹	£1.3bn	£1.1bn	0.4%
Agriculture, Mining, Gas and Electricity	£0.2bn	£0.1bn	0.4%
Wholesale, retail trade, accommodation and food services ²	£0.0bn	£0.0bn	0.0%

¹ Other services' as defined in the SIC code manual include repair of goods, activities of NGOs, charities, trade unions and political bodies.

² The Wholesale, retail trade, accommodation and food services sector shows no direct impact as there are no direct use cases that are captured in this sector group. Please note that typical delivery services that could be associated with retailers are captured in the Transport and Logistics sector.



What is multi-factor productivity?

Multi-factor productivity measures the efficiency of the economy at producing output, by gauging how much output is produced for every input (labour, capital and land included). Another way to think of this is that it measures the total efficiency of all inputs into production, rather than just focusing on one input, such as labour. It's important to stress that our multi-factor productivity estimates are based on an approximation

and are not exact. This is because the true relationship between the inputs used in production, and output, in each sector of the UK economy are unknown. However, we have used an approximation that allows us to use our knowledge of input costs, and the net cost savings from drones adoption, to infer the approximate changes in multi-factor productivity associated with these costs and changes.

Using technology for good

Revolutionising emergency services at accident scenes

By 2030, accident response drones may well be a common sight above the UK's roads. They will enable live data from accident scenes to be shared in real time with the emergency services, meaning they know what to expect and can arrive fully prepared.

Drones will also be able to record and store the evidence from an accident quickly and without intrusion, reducing the amount of time it takes to reopen the road. Multiple autonomous drones may be sent to an accident site to work in concert. In addition to a drone providing live-streamed video, there may be a drone acting as a 5G cell tower to ensure effective communication between the emergency services.

There could also be a drone tasked with capturing a 3D and thermal model of the accident site to enable rapid AI analysis in combination with other feeds from smart sensors installed on the road and/or in the vehicles, and other inputs such as road video feeds and relevant big data such as weather and typical accident rates. This analysis could then be used to validate remedial actions, extrapolate the likelihood of a similar accident occurring elsewhere in on the road network and put preventative measures in place as appropriate.

Accident response drones may also open up new revenue streams for the public sector; for example, the data could be sold to insurance companies, so they have a more accurate view of the basis of any claims.



Supporting search and rescue missions

Search and rescue operations stand to reap major benefits from drones, as the sensors they carry can continue to operate in poor and inhospitable conditions where humans would struggle to work effectively or safely. This capability helps keep personnel away from dangerous situations while also removing the need for more expensive options such as helicopters. The independent offshore lifeboat service at Caister, Norfolk, has been testing a fleet of waterproof drones. They are fitted with floodlights and cameras for use during search and rescue operations and are configured to beam back live footage to lifeboat screens, allowing teams make better decisions based on real-time data. Discussions are underway with the Civil Aviation Authority (CAA) about whether the drones may be used regularly.





Protecting firefighters

Drones can be used for inspecting sites where fire makes areas difficult to access. Advanced sensory data from drones can inform firefighters about alternative routes into a burning building and help them avoid dangerous areas and situations. Drones equipped with infrared sensors can help firefighters identify people trapped in burning buildings and direct hoses more accurately.

Benefits are already starting to be seen in the UK; for example, the Greater Manchester Fire and Rescue Service has been using drone technology since 2015, and is one of the world's first fire services to set up a round-the-clock drone capability. The service initially conducted trials with one drone and a few trained pilots. At one point during the trials, drone footage alerted the team to the fact that several firefighters were next to an unsupported wall.

When deployed effectively, and as drones become smarter, the real-time, life-saving data captured by drones can be a real game changer for emergency services in the UK.

628,000 people in the drone economy

Across all industries, the adoption of drones will inevitably impact on jobs as we know them. New jobs will be created by the changes in productivity and consumer demand resulting from drone usage, and in the drone value chain. There will also be need for new types of workers to think creatively about how drones can be developed and applied, and to build, maintain, operate, and regulate the devices and related technologies. Businesses that engage with drone technology open up a range of exciting opportunities to upskill their existing staff.

All of this will result in the creation of new jobs that would not have existed without drone technology. As well as hardware and software developers to keep up with demand, we will need a robust monitoring system that can manage increased traffic flow to ensure the airspace remains safe.

Given these various impacts we expect, as with GDP, that the impact of drones on jobs through to 2030 will be substantial and follow an S-curve profile. We estimate that a significant 628,000 people will be working in the drone economy.

UK cities and regions rising to the challenge

Five cities and regions across the UK are helping to design the future use of drones to meet a wide range of local needs. Over the coming months, Bradford, London, Preston, Southampton and the West Midlands will take part in Nesta's Flying High Challenge, exploring how drones can support their public services, as well as examining the commercial opportunities they might provide and public attitudes towards them.

The initiative aims to engage local authorities and businesses in thinking about what they want their skies to look like in the future and how drones can work for them. As drone technology and regulations evolve, this 'bottom up' approach is likely to feed into ongoing consultations with members of the public.





Drone-enabled planning and surveying on construction sites

In the construction industry, drones are already providing cheap and efficient ways to map sites and track construction progress against schedule and the original design. Drones offer an effective method of collecting three-dimensional information and integrating it with existing building information modeling (BIM) systems.

Tangible benefits of drone use compared to traditional methods include:

- **Increased efficiency** – a site survey can be up to 400 times quicker.
- **Lower costs** – cost savings of c.40%.
- **Survey grade accuracy** – comparable to traditional, labour intensive land surveying, accuracy is typically 3cm horizontally and vertically, with a pixel in an orthomosaic map representing 3cm in real life.

- **Enhanced data set** – improved photographic visualisation in 2D and 3D.

Existing drone software platforms deliver a fully three-dimensional ‘as built’ representation of a surveyed site which can be compared with original design CAD to ensure adherence to architectural plans.

Embedding periodic drone flights in the construction lifecycle can provide a compelling ‘golden record’ of all construction activities, allowing businesses to manage operations and contractors from initial site survey to project completion. This indisputable data can be accessed in the cloud by multiple stakeholders across multiple locations, enabling unambiguous comparison of site progress at agreed date intervals, virtually eliminating disagreements about project status and providing valuable evidence in case of litigation.

Over 76,000 drones in the UK skies

Turning to the number of drones that will be flying in UK airspace, we've estimated the UK's total population of drones that will be in use by commercial organisations and government in 2030. As Table 2 shows, we project that there will be more than 76,000 drones flying over the UK, split across several different industries.

Table 2: Estimated number of drones in UK skies in 2030, by sector

Sector	Estimated number of drones in 2030
UK wide	76,233
Public and Defence, Health, Education and other services	27,521
Agriculture, Mining, Gas and Electricity	25,732
Transport and Logistics	11,008
Construction and Manufacturing	4,816
Technology, Media and Telecommunications	4,541
Financial, Insurance, Professional and Administrative Services	2,514

Helping agribusinesses become more efficient and sustainable

In the agricultural sector, drones are already being used for crop spraying and health assessments. Certain drones combine normal and thermal cameras to deliver a level of insight into field crop health that is not obvious to the naked human eye, including thermal imaging can detect dry areas and ensure water is delivered where required. Low flight costs also offer an opportunity to frequently overfly field crops and create a timelapse view that highlights any issues.

In the future, the use of drones will be driven by AI routines that launch drones to collect crop information based on a particular trigger event, be it periodicity or a big data event such as an unseasonably wet or dry spell. The drones will fly autonomously and the data captured will be analysed by AI. Actions such as harvesting, irrigation or spraying may then be launched, using the appropriate combination of autonomous robotics.



Managing remote mining operations

Drones are providing mining companies with new and efficient ways to supervise the extraction process and improve mining site management across multiple, often remote, locations.

Adding value at each stage of the mining cycle, drones can be used for ore exploration (detection of geochemical structures), logistics management (monitoring of haul roads condition) and environmental reporting (emissions monitoring). By creating a 3D digital twin of mining sites drones enable accurate volumetric measurements of extracted ore, all from the safety and comfort of the company office. The 'golden record' captured by drones also helps build trust with senior stakeholders and investors.

There is also a glimpse of the future with the use of 'drone in a box' solutions. These start with the usual desk-based mission planning which uses software to mark the area to be flown to, for example, to calculate the volume of a stockpile. The software then determines the flight path and the payload such as a still or video camera is also selected. The drone will automatically equip itself with the selected payload, launch itself from the box, carry out the planned flight and land itself back at the 'box' or base station. It will then upload the captured data and carry out other steps such as swapping or charging batteries all without any direct intervention from a pilot.

We expect this base station, pilot-free concept to become ubiquitous and to increase in sophistication as genuinely autonomous (rather than automatic) drones enter the commercial drone space, integration with other sensors and IT systems improves and the units become man-portable and self-powered through solar or other means.

Drone automation without the manual interfaces

For drone technology to be fully capitalised on, we predict that end-to-end system integration will be critical. Only by automating the integration of the drone-captured data such as a 3D digital twin platform with existing enterprise wide IT architecture and other robotics, will companies be able to maximise efficiencies from the deployment of drones.

Within asset maintenance drones could identify infrastructure degradation. Machine learning could then categorise this in terms of criticality and then automatically link back to the existing company systems (including the Enterprise Asset Management (EAM), Enterprise Resource Planning (ERP), and maintenance management systems). If the degradation is beyond a certain level, the systems could then automatically raise the appropriate work request and schedule an engineer (or robot) to complete the repair work. The final closure of the work request may require the drone to be sent back to the area to validate the repair and update the inspection records in the asset management system with the new asset condition.

Turning potential into reality

How to seize the drone opportunity?

As organisations of all types continue to digitise in the coming years, drones will become one of the most important sources of data and insights and a key part of any Intelligent Digital strategy. If a business is operating in a sector that is gearing up for fast adoption, it will have to move quickly to avoid losing out to faster-moving competitors. Even sectors where the disruptive potential of drones is lower will not be immune to their impacts. In every industry, doing nothing is not an option.

How can organisations embrace an intelligent digital approach, and begin the drone journey and keep pace with the competition? Here are four steps to help position a business as a leader in realising the potential of drones...

1 *Establish the implications of drones*

Carry out a strategic review of the technological developments around drones and use cases relevant to your business. Examine the operational challenges that drones can help overcome, including when combined with other emerging technologies such as AI.

2 *Formulate and prioritise the response*

Having scanned the evolving landscape, the business needs to shape and prioritise its strategic response to the rising take-up of drones. This includes asking questions like: how can drones help to achieve business goals? Does the organisation want to be an early adopter or fast follower? How can we integrate drones with our existing digital systems? Is the solution technologically, economically and socially feasible?

3 *Look beyond technology, by putting the right talent and culture in place*

While investment in drones may currently appear expensive, costs will decline over the coming years, as drone services and the related software become more standardised and commoditised. To make the most effective use of drones, organisations will need to develop a data-driven culture and ensure that drone-captured data is seamlessly integrated with other digital systems to deliver clear insight

and enable actions to be taken at the optimum time. Talent requirements will also change, with greater need for data scientists and robotics engineers. And there will be an increase in the value of human skills that can't be replicated by machines, such as creativity, leadership, problem-solving and emotional intelligence. This is the balance of business understanding with technology innovation and human insight.



4 Ensure the right levels of governance, controls and trust

In capitalising on all areas of emerging technology, trust and transparency are critical and drones are no exception. It's imperative that people feel confident and reassured that the devices flying over their heads are working in their best interests, concerns over privacy are very real and there is a lot to do to build trust and confidence. This means any technology-enabled transformation using drones must take account of societal and ethical implications, and include steps to build stakeholder trust. These should include implementing mechanisms to assure the quality and integrity of data inputs, and gaining feedback on how stakeholders such as customers and the general public perceive the business's use of drones. While the commercial imperative of drone use is there, today's customers increasingly demand businesses to deliver positive social and environmental outcomes as well as strong financial performance.

Some questions to help map out the way forward

Whatever their size or industry sector, the market leaders of tomorrow are likely to be exploring the possibilities and setting their strategies for drones today. We believe there are four questions any business should address now if it wants to make the most of the drone opportunity:

- How vulnerable is your business model to drone-driven disruption and how soon will that disruption arrive?
- What game-changing openings are there within your market, and how can you take advantage of them?
- Do you have the talent, data and technology you'll need to do this?
- How can you build transparency and trust into your drone platforms and applications?

Get the answers to these questions right, and you'll be well-placed to emerge as a winner from the forthcoming drone revolution – a seismic shift that will bring major implications for the UK's citizens, industries, economy and employment. Now is the time to explore and embrace the potential of drones and lay the foundations for success in the drone-enabled world of 2030.

Defining drones

The term ‘drone’ has a wide range of uses and has been applied to vehicles ranging from sub-sea craft to satellites. For the purposes of this report we define drones as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UASs), made up of a ground-based operator, the drone itself, and a communications system linking the two.

Under this definition, drones are essentially flying robots that can operate with varying degrees of autonomy. Some are fully remote-controlled, while others are equipped to fly and navigate automatically using on-board flight-planning software in conjunction with GPS and sensors. Drones can be equipped with a range of sensors including cameras, video equipment, or others such as infrared sensors for heat detection.

It is the data acquired by the sensors attached to the drones that represents the real value of drones to organisations. The benefits are realised by taking this data, and then processing, analysing and interpreting the results within the wider environment, thus enabling business insights to be generated.

The use of drones can be broadly divided into two main categories: recreational and commercial. The first type involves individuals using drones as a hobby or for enjoyment. The second involves the use of drones to generate an economic return or deliver public service. The rules of the UK’s Civil Aviation Authority impose restrictions on both categories of drone usage, including an effective ban on most uses that go ‘beyond visual line of sight’ (BVLOS).

Types of drone that fall within our definition include:

- **Fixed wing** – Uses aeroplane-like wings to provide lift rather than rotors;
- **Single rotor** – With a single rotor to provide lift, plus a tail rotor to control direction;
- **Fixed-wing hybrid VTOL** – Combines fixed-wing capabilities with vertical take-off-and-landing capability; and
- **Multi-rotor or multi-copter** – With multiple rotors, usually four (known as ‘quadcopters’).

Drones also come in various sizes:

- **Micro** – Fit in the palm of your hand. Mostly used for recreational purposes indoors;
- **Small** – Between 50cm and 100cm. Mostly used for filming or photography;
- **Medium** – Twice the size of small drones. Can carry professional cameras or small parcels;
- **Large** – Able to carry heavier cargo; and
- **Supersize** – Able to carry people or very heavy loads.



How we gauged the impact and potential of drones for the UK

To estimate the impact and potential of drones, our team conducted an ambitious, three-phased top-down analysis.

- **Phase 1** – Estimating the net cost savings from drones in the UK. This involved drawing on PwC’s previous ‘*Clarity from Above*’ report, which looked at expected global gross cost savings from drones, and estimating the UK’s portion of these cost savings based on three factors: the UK’s share of GDP in each sector; the ‘drones friendliness’ of the UK’s regulatory framework; and the UK’s general propensity for uptake of new technologies, as measured through the *2017 Global Innovation Index*. We then used external data on drones running costs and expert PwC analysis to estimate the net cost saving per UK sector from uptake of drones.
- **Phase 2** – Estimating the implied multi-factor productivity increases in the UK. By merging our estimated net cost savings from drones uptake with data on the total cost of capital and employment per UK sector, we calculated the implied increase in multi-factor productivity in each sector. We made assumptions around the profile of uptake based on past experience of technology diffusion (being ‘S-shaped’), and applied this to the UK.
- **Phase 3** – Projecting the total economic impact of drones. We input our multi-factor productivity figures into our Computable General Equilibrium (CGE) model, to work out the aggregate effects of drones uptake on UK GDP up to 2030, and the total number of jobs impacted by drones as a result. The CGE model captures all economic interactions in the UK economy; including, trade and spending between firms on one another’s goods and inputs, spending by consumers on goods and their investment decisions, and dynamics in the market such as demand for factors such as capital and labour, trade, employment and wage effects.



We're projecting the net effect of drones on GDP – not GDP itself

Our projection for the impact of drones on GDP has been generated using a large-scale dynamic economic (CGE) model of the global economy. The model is built on the Global Trade Analysis Project (GTAP) database, which provides detail on the size of 57 different economic sectors in 140 different countries, and on how they trade with each other through their supply chains. When considering the results, there are two important factors that you should take into account:

1. Our results show only the economic impact of drones. These effects may not show up directly in future economic growth figures, as there will be many positive or negative forces that either amplify or cancel out the potential effects of drones (e.g. shifts in global trade policy, financial booms and busts, major commodity price changes, geopolitical shocks, etc.).

2. Our economic model results are compared to a baseline of long-term steady state economic growth. The baseline is constructed from three key elements: population growth, growth in the capital stock, and technological change. The assumed baseline rate of technological change is based on average historical trends. It is very difficult to separate out how far drones will just help economies such as the UK to achieve long-term average growth rates (implying the contribution from existing technologies phase out over time), or simply be additional to historical average growth rates (given that these will have factored in major technological advances of earlier periods).

These two factors mean that our results should be interpreted as the potential 'size of the economic prize' associated with drones, as opposed to direct estimates of future economic growth.

Aggregate impact of drones

We expect the adoption of drones in the UK to follow an ‘S-curve’ pattern. The resultant impact of drones on UK GDP against baseline forecast, and profile of impact 2017-2030 is also therefore predicted to follow an ‘S-curve’ pattern as shown in Figure 1.

Dynamic impacts

Over time, the direct GDP effects of productivity gains from rising usage of drones will be supplemented by dynamic impacts from resulting shifts in consumer demand, business investment, and input demand. Businesses will value the cost, productivity and workforce effects, freeing up investment for new areas. Meanwhile, consumers will be attracted by cheaper prices and, over time, greater varieties and quality of goods to choose from, as new firms enter the market with new product in response to increased profits. In turn, this increased consumption will create a virtuous cycle of more demand, greater revenue, more firm entry and investment, more demand, and so on.

As noted above, we’ve quantified the impact of drones on UK GDP to include these dynamic effects using Computable General Equilibrium (CGE) modelling. As Figure 2 shows, the CGE model quantifies the multidirectional relationships between the government (which subsidies and taxes goods, services and labour); households (which supply labour and capital and receive wage and capital income for their work); and firms (which buy goods and services from one another, try to maximise their profits and trade internationally) in a realistic, closed ecosystem framework.

We quantified these relationships using this model structure along with past data from the GTAP database on expenditure by each sector on one

Figure 1: Aggregate impact of drones on UK GDP against baseline forecast, and profile of impact, 2017-2030

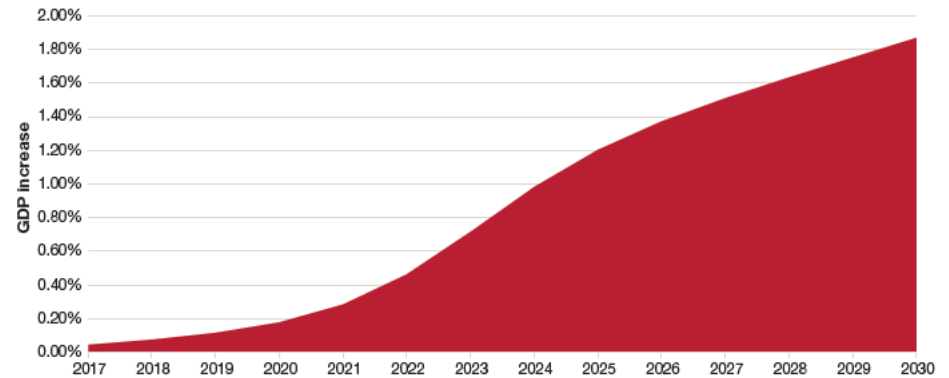
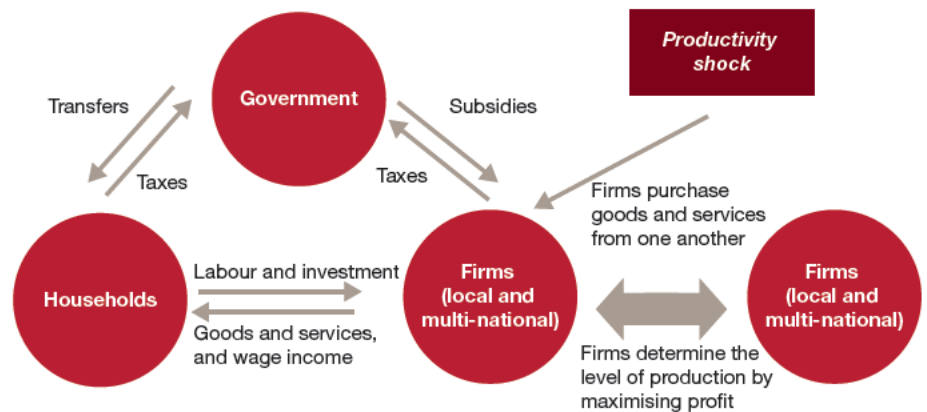


Figure 2: Computable General Equilibrium (CGE) modelling



another’s final goods and inputs, as well as on general consumption, government expenditure, trade and investment levels at a sector level.

Our analysis shows that drones will mainly impact the economy directly through the production side via productivity enhancements, as firms replace traditional labour and business processes with drones. The CGE model is able to quantify the net impact of these productivity innovations on the

UK economy through the resulting interactions that occur in the economy due to increased business productivity in different sectors. We’ve therefore separately estimated the direct ‘productivity shock’ in each sector of the UK economy from drones uptake (see Phase 1). It is this initial productivity impact that leads to the effects on trade, investment and consumption outline above as firms interact with each other and with households and the government.



The productivity channel will produce winners and losers

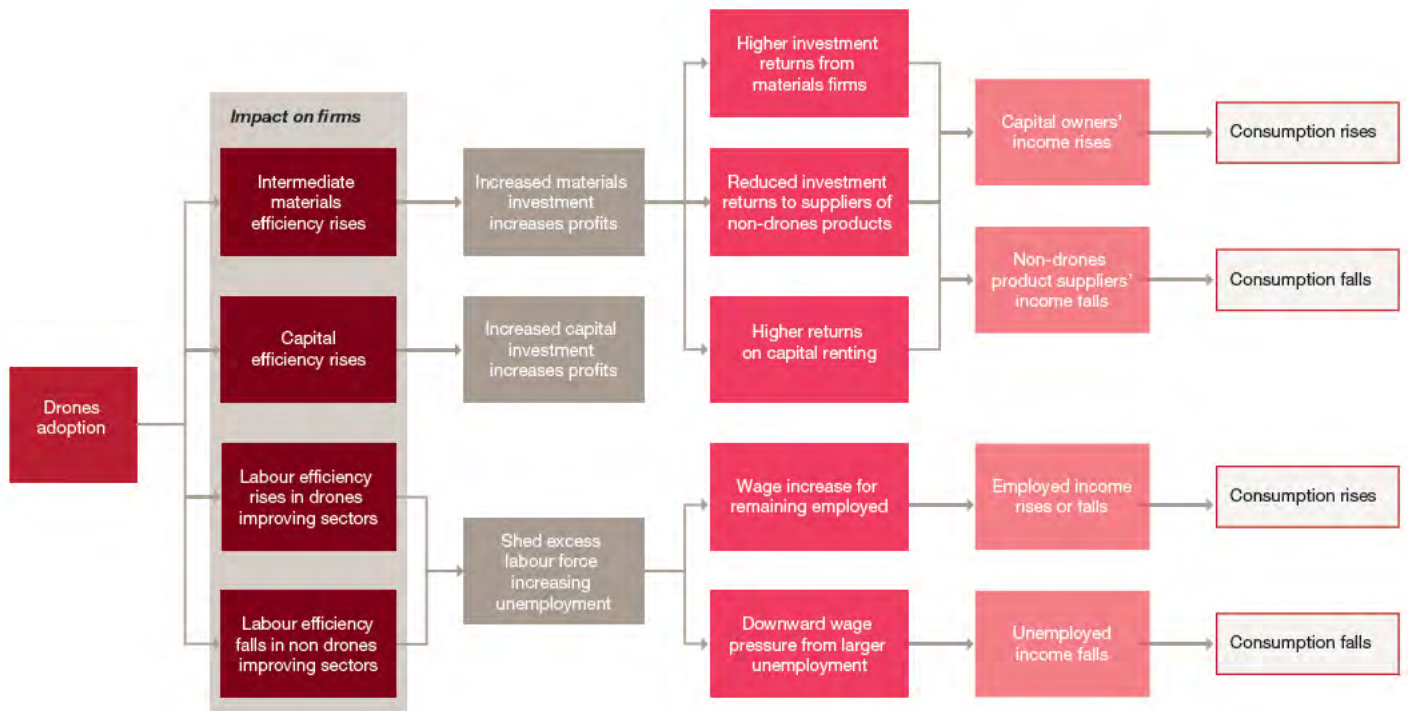
Once businesses adopt drones, the transmission mechanism of their impact from the firms to consumer is complex, as outlined in Figure 3. It is important to note that there will be relative winners and losers in each area of the economy as a result of drones uptake, but everyone is better off in a world with drone technology. For example, among firms that supply intermediate inputs, the successful ones will be those that supply inputs to sectors that experience the largest uplifts in productivity from using drones, and where the productivity enhancements do not allow substitution away from their inputs towards a less expensive alternative.

Meanwhile, on the consumer side, households that own capital stand to benefit relative to non-capital owners, and those capital owners in high drones-productivity impact sectors will see a particularly large rise in income,

as the rent price of capital increases in line with its productivity. The net impact on labour income is slightly unclear, as efficiency increases may result in part of the labour force being shed, putting downward pressure on consumption.

As noted before, this transmission mechanism captures only the first round of effects on economic activity. Once aggregate consumption rises due to the increase in collective income and company profits, this stimulates the entry of new dynamic firms, which in turn increases consumption further by boosting consumers' income. These effects continue to iterate themselves until the economy reaches its new long-run equilibrium.

Figure 3: The productivity channel of impact in the CGE model



Our calculation of drone numbers

Our estimate for the UK's total complement of drones operating in commercial and government applications in 2030 is 76,233. We've calculated this figure by using forecasts from a European Union study and existing PwC research to identify the approximate number of drones likely to be in the EU's skies in 2030. Taking this number, we then apportioned it down to the UK economy and across different sectors, using what we know about the size of the UK relative to the EU, and the extent to which the UK's environment is 'drone friendly'. These figures helped us to understand the net savings from using drones for each sector, after taking into account the cost of running drones.



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